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Forecast for northern and central coastal British Columbia coho salmon in 2002

Prévisions concernant le saumon coho de la côte ouest et nord de la Colombie-Britannique en 2002

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Abstract

This Research paper documents forecasts of marine survival and abundance for the coho of northern and central coastal British Columbia (Statistical Areas 1 to 13), including the upper Skeena conservation area.

Marine survival:

In 2002, marine survival at the three northern indicators is expected to be below the means of their respective periods of observation.

indicator	model	$\hat{s}_{2002}$	(50% CI)	observed mean and period of observation (year of sea-entry)	
Lachmach	sibling regression	0.075	(0.06–0.09)	0.10	(1987 – 2000)
Toboggan Creek hatchery	from Lachmach	0.025	(0.016–0.04)	0.039	(1987 – 2000)
Fort Babine hatchery	from Lachmach	0.011	(0.007–0.02)	0.025	(1993 – 2000)

The period of observation is short for all three indicators. The survival rate of wild Toboggan Creek coho should be comparable to Lachmach but cannot be reliably forecast.

Abundance forecast

Estimated smolt production from Lachmach in 2001 was 3.6×10^4, which is slightly above the observed mean of 3.1×10^4 (1987 – 2000). That combined with below-mean marine survival produce a forecast return of 2.7×10^3 (50%CI: 2.2×10^3 – 3.3×10^3) which is the mean return observed over the period 1988 to 2001 (return years). The forecast of abundance for wild Toboggan coho is 1.4×10^3, which is considerably less than the mean total return of 4.7×10^3 (return years 1988 – 2001). Assuming an exploitation rate of 36% (i.e., same as 2001), the wild escapement to Toboggan would be 8.7×10^2, including terminal sport fisheries. That escapement is considerably below the mean of the available observations (2.1×10^3; 1988 –2001). Abundance of Babine Lake coho is forecast to be 2.2×10^4 (50%CI: 1.7×10^4 – 3.0×10^4) using the preferred S-R model. This return is above the mean of the time series (1.2×10^4; 1946 to 2001). Assuming an exploitation rate of 0.55, escapement would be 9.4×10^3, which is approximately 78% of the provisional escapement target for the aggregate (1.2×10^4; Holtby et al. 1999b).

The stock-recruit and time series forecasts of abundance for Babine coho and the average-stream indices of the 12 north and central coastal aggregates show some indication of geographic patterning but do not indicate any conservation concerns in the area, with the possible exceptions of Areas 4C/5 and 13. Escapement data are very poor in Area 4C/5 so it is difficult to determine the extent to which the poor escapements are due simply to limited data. Escapement data are better in Area 13 and there are other indications, including fresh water juvenile surveys, that are consistent with the poor status indicated by the escapement index. The total abundance and the escapement of coho in the northern part of the forecast region (Areas 1, 3, 4L and 4U) will average to above-average in 2002. In the areas around Hecate Strait (Areas 2E, 4C/5, 6 to 12), total abundance will be well below average to average but provided fisheries do not expand much over levels in 2001, escapements will be average in most of those areas. Forecast abundance in Johnston Strait streams (Area 13) can be characterized as well below the mean. Without further investigation of this situation and a demonstration that status is actually better than indicated by the index used here, expansion of fisheries in the part of the coast should be discouraged.

Forecast characterizations for the aggregates considered. Probability values between 35% and 65% were characterized as average; probabilities less than 15% or greater than 85% were characterized as either well below or well above average respectively. We have arranged the aggregates into six geographical groups based on geography, distributions of coded-wire tagging (CWT's) in fisheries and on productivity (Holtby et al. 1999b). This is a convenient way to summarize the forecasts because forecasts of abundance

and escapement for average stream indices are useful only in the context of how far they deviate from the long-term means of their respective time series.

			total return (abundance)		escapement		
aggregate	group	model	forecast P †	characterization	forecast P	characterization	% of S_{max}
Area 2W	1	3YRA	35%	average	56%	average	43%
Area 1	2	3YRA	38%	average	70%	above average	97%
Area 3	2	S-R	71%	above average	90%	well above average	96%
Area 4L	3	S-R	54%	average	90%	well above average	111%
Area 4U	3	S-R	73%	above average	85%	well above average	125%
Babine Lake aggregate	3	S-R	63%	above average	75%	above average	85%
Area 2E	4	3YRA	11%	well below average	46%	average	31%
Area 4C/Area 5	4	LLY	5%	well below average	25%	below average	40%
Area 6	4	3YRA	23%	below average	55%	average	36%
Area 7	4	3YRA	29%	below average	62%	average	65%
Area 8	5	3YRA	11%	well below average	43%	average	43%
Area 9/12	5	3YRA	38%	average	78%	above average	55%
Area 13	6	3YRA	4%	well below average	28%	below average	13%

† Proportions of observed abundance or escapement less than the forecast value. These calculations assume a log-normal cumulative probability distribution with mean and standard deviation calculated over the observation period 1950 (1946 for Babine) to 2001 (return years).

Résumé

Sont présentées des prévisions de la survie en mer et des effectifs du saumon coho dans divers secteurs des côtes nord et centrale de la Colombie-Britannique (zones statistiques 1 à 13), y compris l'aire de conservation du cours supérieur de la Skeena.

Survie en mer

On prévoit que les taux de survie en mer en 2002, déterminés aux trois points repères du nord, seront inférieurs aux moyennes pour les périodes d'observation respectives.

Point repère	Modèle	$\hat{s}_{2002}$ (IC de 50%)	Moyenne observée et période d'observation (année d'entrée en mer)
Rivière Lachmach	régression des germains	0,075 (0,06–0,09)	0,10 (1987-2000)
Écloserie du ruisseau Toboggan	à partir de Lachmach	0,025 (0,016–0,04)	0,039 (1987-2000)
Écloserie de Fort Babine	à partir de Lachmach	0,011 (0,007–0,02)	0,025 (1993-2000)

La période d'observation aux trois points repères est courte. Le taux de survie du coho sauvage du ruisseau Toboggan devrait se rapprocher de celui du coho de la rivière Lachmach, mais on ne peut le prévoir de façon fiable.

Prévisions des effectifs

La production estimative de smolts dans la rivière Lachmach en 2001 se chiffrait à $3,6\times10^4$, nombre légèrement supérieur à la moyenne de $3,1\times10^4$ observée (1987–2000). Ce niveau de production, joint au fait que le taux de survie en mer est inférieur à la moyenne, donne une remonte prévue de $2,7\times10^3$ cohos (IC de 50 % : $2,2\times10^3$ – $3,3\times10^3$), ce qui concorde à la remonte moyenne observée pendant la période allant de 1988 à 2001 (années de remonte). Dans le cas du coho sauvage du ruisseau Toboggan, les prévisions situent les effectifs à $1,4\times10^3$, nombre nettement inférieur à la remonte moyenne totale de $4,7\times10^3$ cohos (années de remonte 1988 à 2001). En supposant que le taux d'exploitation en 2002 sera le même qu'en 2001 (36%), on prévoit que l'échappée de coho sauvage vers le ruisseau Toboggan atteindra $8,7\times10^2$, y compris les prises sportives en estuaire. Ce niveau d'échappée est nettement inférieur à la moyenne des observations disponibles ($2,1\times10^3$; 1988–2001). Selon les prévisions reposant sur le modèle de régression sur les germains, les effectifs de coho du lac Babine atteindront $2,2\times10^4$ (IC de 50% : $1,7\times10^4$ – $3,0\times10^4$), ce qui dépasse de beaucoup la moyenne de la série temporelle ($1,2\times10^4$; 1946-2001). En supposant que le taux d'exploitation atteindra 0,55, on prévoit que l'échappée atteindra $9,4\times10^3$, ce qui correspond approximativement à 78% de la cible d'échappée provisoire pour l'ensemble ($1,2\times10^4$; Holtby *et al.*, 1999b).

Les prévisions issues de modèles stock-recrutement et de séries chronologiques des effectifs pour le coho du lac Babine et les indices du cours d'eau moyen des 12 stocks combinés de la côte nord et de la côte centrale montrent certains signes de tendances géographiques mais aucun problème de conservation dans la région, sauf peut-être dans les zones 4C/5 et 13. Les données sur l'échappée pour la zone 4C/5 étant médiocres, il est difficile de déterminer dans quelle mesure les faibles échappées sont imputables uniquement à la carence de données. Les données sur l'échappée pour la zone 13 sont meilleures et d'autres indicateurs, dont des relevés des juvéniles en eau douce, étayent la conclusion, tirée de l'indice d'échappée, à l'effet que le stock est en mauvais état. Le total des effectifs et l'échappée dans la partie nord de la région de prévision (zones 1, 3, 4L et 4U) se situeront au niveau ou au-dessus de la moyenne en 2002. Dans les

zones du détroit d'Hécate (zones 2E, 4C/5, 6 à 12), le total des effectifs sera grandement inférieur ou égal à la moyenne mais, pourvu que les pêches se rapprochent des niveaux d'exploitation de 2001, les échappées seront moyennes dans la plupart de ces zones. On peut caractériser les effectifs prévus pour les cours d'eau tributaires du détroit de Johnstone (zone 13) comme étant grandement inférieurs à la moyenne. Si aucune autre étude de cette situation n'est faite pour démontrer que le stock est en meilleur état que ne l'indique l'indice utilisé dans la présente étude, on devrait décourager l'expansion des pêches dans ce secteur de la côte.

Caractérisation des prévisions pour les ensembles considérés. Les valeurs des probabilités entre 35% et 65% ont été caractérisées comme des valeurs moyennes et celles inférieures à 15% ou supérieures à 85%, comme des valeurs soit grandement inférieures ou grandement supérieures à la moyenne, respectivement. Nous avons réparti les stocks combinés en six groupes géographiques d'après les caractéristiques géographiques, les distributions dans les prises des cohos portant une marque métallique codée et la productivité (Holtby *et al*., 1999b). C'est un moyen pratique de résumer les prévisions parce que les prévisions des effectifs et de l'échappée reposant sur des indices du cours d'eau moyen ne sont utiles que dans la mesure où elles dévient des moyennes à long terme de leurs séries temporelles respectives.

			Remonte totale (effectifs)		Échappée		
Stock combiné	Gr.	Modèle	Prévision *P**	Caractérisation	Prévision *P*	Caractérisation	% de S_{max}
Zone 2W	1	3 YRA	35 %	moyenne	56 %	moyenne	43 %
Zone 1	2	3 YRA	38 %	moyenne	70 %	supérieure à la moyenne	97 %
Zone 3	2	S-R	71 %	au-dessus de la moyenne	90 %	grandement supérieure à la moyenne	96 %
Zone 4L	3	S-R	54 %	moyenne	90 %	grandement supérieure à la moyenne	111 %
Zone 4U	3	S-R	73 %	au-dessus de la moyenne	85 %	grandement supérieure à la moyenne	125 %
Lac Babine	3	S-R	63 %	au-dessus de la moyenne	75 %	supérieure à la moyenne	85 %
Zone 2E	4	3 YRA	11 %	grandement inférieure à la moyenne	46 %	moyenne	31 %
Zones 4C/5	4	LLY	5 %	grandement inférieure à la moyenne	25 %	inférieure à la moyenne	40 %
Zone 6	4	3 YRA	23 %	inférieure à la moyenne	55 %	moyenne	36 %
Zone 7	4	3 YRA	29 %	inférieure à la moyenne	62 %	moyenne	65 %
Zone 8	5	3 YRA	11 %	grandement inférieure à la moyenne	43 %	moyenne	43 %
Zones 9-12	5	3 YRA	38 %	moyenne	78 %	supérieure à la moyenne	55 %
Zone 13	6	3 YRA	4 %	grandement inférieure à la moyenne	28 %	inférieure à la moyenne	13 %

*Les pourcentages des effectifs et des échappées observés sont inférieurs aux prévisions. Les calculs reposent sur l'hypothèse d'une distribution log-normale des probabilités cumulatives dont la moyenne et l'écart-type sont calculés sur la période d'observation allant de 1950 (1946 pour le stock combiné du lac Babine) à 2001 (années de remonte).

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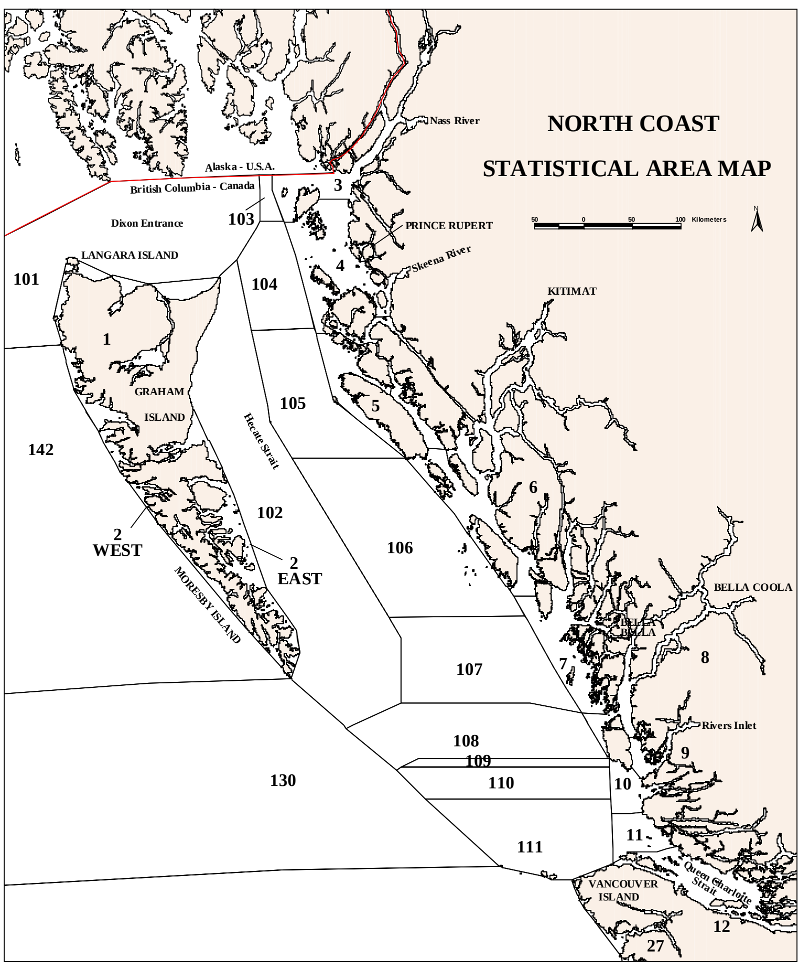
1. Introduction

In this Research Document we detail:

1. Performance of the 2001 forecasts for coho aggregates in north and central coastal British Columbia (Holtby and Finnegan 2001)
2. A forecast of marine survival and total return for the wild indicator stock of the Lachmach River (Area 3; Work Channel);
3. Forecasts of marine survival for the Toboggan Creek and Fort Babine hatchery indicators (Area 4; upper Skeena conservation area);
4. Forecasts of the total return and escapement of the Babine Lake (Area 4; upper Skeena conservation area) coho aggregate;
5. Forecasts of indices of total coho return to Statistical Areas 1, 2E, 2W and 3 through 13.

Forecasting methods conform to those of past forecasts in this area (Holtby and Finnegan 2001; Holtby et al. 2000, 1999a). We have added forecast for the combined areas of 9 to 12 of the Central Coast.



2. Data Sources

Catches and escapement data for coded-wire tagged coho from the Lachmach River (wild indicator) and Toboggan Creek and Fort Babine hatchery indicators were obtained from an online database maintained by the Alaskan Dept. of Fish and Game[1]. CWT recovery data for 2001 are preliminary and may change as catch and escapement estimates are finalized. Escapement data for Lachmach River coho were obtained from program sources in the Stock Assessment Division. Visual escapement estimates for streams in Statistical Areas 1 to 7 were obtained from stock assessment staff in the Prince Rupert Office. (pers. comm. B. Spencer, DFO, Prince Rupert). Escapement data for the Babine Lake coho aggregate were obtained from a database maintained by the Stock Assessment Division in the Prince Rupert Office. Escapement data for Toboggan hatchery and wild coho were obtained from the Toboggan Creek Enhancement Society (pers. comm. M. O'Neill, TCES, Smithers). Escapement data for central coastal British Columbia were obtained from stock assessment staff in Campbell River (pers. comm. J. Gordon, DFO, Campbell River). All data from 2001 should be considered preliminary and subject to revision as escapement estimates are finalized. Since 1998 Babine hatchery has been releasing adipose-clipped coded-wire tagged fish (AdCWT) fish with right maxillary clips in addition to AdCWT fish. Maxillary clips are known to reduce survival by 25% to 33% compared to AdCWT coho of similar size (D. Bailey, HEB, Vancouver) but we have not attempted to estimate this survival impact since the fence counts at Babine have not consistently separated the two tag-clip groups.

Estimates of exploitation rate are based partially on the recoveries of CWT's in Alaskan fisheries and on estimates of exploitation rate derived from reconstructions of Skeena/Nass River sockeye fisheries in Statistical Areas 1 to 5 (pers. comm. S. Cox-Rogers, DFO, Prince Rupert).

Many of the analyses presented in this Working Paper use reconstructed time series of exploitation rate on Skeena coho. These reconstructions are derived from relationships between exploitation rate and effort stratified for gear, area and time for the period 1965 to 1987. Exploitation rate estimates of fishery-specific exploitation rate derived from coded-wire tags first became available in 1988 in northern BC. The reconstructions are part of a comprehensive assessment of coho in the northern boundary area (Anon. 2002; Shaul and Van Allen 2001; Holtby et al. 1999b).

3. Forecasting Models and Retrospective Analysis of Predictive Power

3.1 Forecasting models

We use three approaches to forecasting in the Working Paper. Where there are time-series longer than about 15 years we use four quasi time-series models. In each model the variable being forecast (v) is first transformed so that

$$Z = \Im(v) \tag{1}$$

where $\Im$ is the transformation and Z is the transformed value of v. The Log transformation was used for abundance. The Logit transformation[2] was applied to proportions such as survival (s). The four models can then be described as follows where Z_{t+1} is the forecast value for time t+1:

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[1] Alaska Department of Fish and Game, Commercial Fisheries: http://tagotoweb.adfg.state.ak.us

[2] $Z_t = \log_e {}^{v_t}\!/_{1-v_t}$

mnemonic	model	Equation
LLY ("Like Last Year")	$Z_{t+1} = Z_t + \varepsilon_t$	(2)
3YRA (3-year average)	$Z_{t+1} = \dfrac{\sum_{k=t-2,t} Z_k}{3} + \varepsilon_t$	(3)
RAT1 (1 year trend)	$Z_{t+1} = \dfrac{Z_t^2}{Z_{t-1}} + \varepsilon_t$	(4)
RAT3 (average 3-year trend)	$Z_{t+1} = \dfrac{\sum_{k=t-2,t} Z_k / Z_{k-1}}{3} Z_t + \varepsilon_t$	(5)

For each model we assume that the error term is normally distributed $(\varepsilon \sim N(0,\sigma^2))$ and is independent of time. For the purpose of estimating uncertainty in the forecast value (Z_{t+1}), an estimate of σ^2 was obtained for the distribution of observed minus predicted for years $1 \ldots t$.

The differences between the four models are summarized in the following Table:

		years used in prediction: 1	years used in prediction: 3 (≈ 1 cycle)
project trends?	NO	LLY	3YRA
	YES	RAT1	RAT3

For Lachmach River coho the marine survival rate was predicted using a "sibling-regression" model, where the total return of age-n.1[3] fish ($A_{t,n.1}$) is predicted from the observed age-n.0 escapement of males ($E_{t-1,n.0}$, 'jacks'):

$$\log_e A_{t,n.1} = b \log_e E_{t-1,n.0} + a + \varepsilon_t \qquad (6)$$

Survival (s_{smolt}) was then calculated by dividing the age-n.1 return in year *t* by the number of smolts counted out of the system in year *t*-1 (N_{smolt}).

All of the approximately 25 coho populations spawning above the Babine River counting fish have been combined into the Babine Lake aggregate. For these coho we have estimates of total escapement from 1946 to 2001. The fence was not operated in 1964. The 1964 escapement in that year was estimated from the Skeena test-fishery index using an iterative contingency-table algorithm (Brown 1974) implemented in Excel®[4] (pers. comm. J. Blick, ADFG, Juneau, AK). Estimates of age composition of returning adults exist for 15 years in the 1970's and 1980's. Age composition in the escapement is significantly related to spawner numbers in the brood year. We used that relationship to estimate age composition in years for

[3] The age designation follows the European convention, which is "number of fresh water winters **.** number of ocean winters". In most northern coho escapement and catch is made up of a mixture of age 1.1 and age 2.1 adults with some age 3.1 animals.

[4] Registered trade-mark of Microsoft Corp., Redmond, WA. Mention of this product does not constitute endorsement.

which there were no data. Using the reconstructed exploitation rate time-series we then estimated total recruitment and did a standard Ricker stock-recruitment analysis (Hilborn and Walters 1992). Recruitment for the 1997 brood year is not yet complete because a significant proportion of the returning adults is age 2.1. To estimate recruitment of age 2.1 fish in the next year we used the number of age-1.1 fish ($N_{1.1}$) and the estimated age composition ($p_{1.1}$) for the current year.

Estimates of escapement to individual streams throughout BC have been made since at least 1950. These estimates are mostly based on visual inspections of the streams. The methods used to inspect the streams, and convert the counts to estimates of escapement, the frequency of surveys, etc., are largely undocumented. These methods are known to differ between systems and to have changed over time. The records are also fragmentary. Nevertheless we think that the time series do contain information about escapement trends in each area.

To extract that information we first coded the various designators for "no-data" to a common missing value indicator. We then scaled the escapement (E) in each stream i to the maximum escapement recorded in that stream across all years t:

$$p_{i,t} = \frac{E_{i,t}}{\max(E_i)} \tag{7}$$

Then the $p_{i,t}$ were averaged across all streams i within each year t to give a time series (p_{max}) for the area as a whole. The "average-stream" or index escapement was constructed by multiplying p_{max} by the average across the i streams of max(E_i). This procedure was carried out for streams aggregated by Statistical Area with some exceptions. Streams of Area 5 were combined with those of coastal sub-area (including the McNeil, the Ecstall) of Statistical Area 4. Doing so grouped streams in Area 4 with similar coastal streams of Area 5. The streams of Areas 9 to 12 were also grouped together.

To construct an index of total abundance we then made some assumptions about the time series of historical exploitation rates. We know from CWT recoveries in ocean fisheries between 1987 and 1994 that coho from the entire North and Central Coast areas have very similar ocean distributions (Anon. 1994). Most coded-wire tags have been recovered in troll fisheries both in Alaska and northern B.C. This lead us to assume that the levels and the temporal patterns in ocean exploitation rates are likely similar between all of the sites in the North and Central Coast. We also know from patterns of CWT recoveries that fish from the lower and middle Skeena are more similar to coho from the more southerly Areas, while fish from the Babine have similar distributions to Area 3 coho. We therefore assumed that the marine exploitation rate time series developed for Toboggan Creek was applicable to all areas except 3 and the upper Skeena. The exploitation rate time series for Area 3 was derived from Lachmach 1987-2001 and from the marine component of Babine from 1950 to 1986. The exploitation rate for the upper Skeena was the average of those for Babine and Toboggan. In using the exploitation rate time series for Skeena populations, the fresh water components of those exploitation time series were removed before application to the other areas.

Forecasts for the Babine Lake and the average-stream indices were made in two ways. First, total returns to the "average stream" within each aggregate were forecast using the four time-series models. Second, the time series of escapement and returns were used as inputs to Ricker stock-recruitment analyses, which were then used to forecast recruitment and returns in 2001 using observed spawner indices in 1998.

The 'average-stream' indices may be effective descriptors of status of coho within a geographical area. Some regrouping might be advisable to combine streams of similar physiography. However, the utility of the average-stream index in describing trends within an area have not been thoroughly explored and no diagnostics have been developed for recognizing situations where the index is unsuitable.

To give the reader a feel for the approximate likelihood of forecast values, the forecasts have been expressed in terms of Z-scores:

$$Z = \frac{x - \overline{x}}{SD} \tag{8}$$

Tabulated values of *Z* and their associated cumulative probability values can be found in most statistical texts but for convenience we have graphed the cumulative probability values for $Z \pm 3$ (Figure 1).

3.2 Retrospective analyses

The relative performance of the models has not varied during previous retrospective analyses (Holtby et al. 1999a, 2000) and consequently those models selected as having the smallest Root Mean Square Error (*RMSE*):

$$RMSE = \sqrt{\overline{\left(v_{observed,t+1} - v_{predicted,t+1}\right)^2}} \qquad (9)$$

and Mean Absolute Deviation (*MAD*):

$$MAD = \overline{\left|\left(v_{observed,t+1} - v_{predicted,t+1}\right)\right|} \qquad (10)$$

in the 2000 forecast (Holtby et al. 2000) were used for the 2002 forecasts.

4. Marine Survival Estimates

4.1 2000 Forecasts compared to marine survivals observed in 2000

Holtby and Finnegan (2001) forecast marine survival rates for the Lachmach wild indicator and for the Toboggan Creek and Fort Babine hatchery indicators. Those forecasts and the observed marine survivals are given in the following Table. The time series of survival and total stock sizes can be found in Table 1.

indicator	forecasting model	forecast survival ($\hat{s}_{2001}$)	50% CI	observed survival (s_{2001})
Lachmach River (Table 4)	sibling regression	0.29	0.23 – 0.35	0.14
Toboggan Creek (Table 5)	regression on Lachmach survival	0.09	0.05 – 0.14	0.083
Toboggan Creek (wild)	observed scalar from hatchery survival	0.15	none given	0.061
Fort Babine (Table 5)	regression on Lachmach survival	0.08	0.04 – 0.15	0.018

For Lachmach wild coho marine survival was less than half of the forecast value and had a probability level of approximately 1%, but nevertheless was well above (Z-score = 2.26; $P \approx 0.02$) the mean of the available time series (0.10; return years 1988 – 2001). The marine survival forecasts for the two Skeena hatcheries are based on the forecast survival for Lachmach so not surprisingly both forecasts were greater than the observed survivals. Survival of Fort Babine hatchery coho was much poorer than forecast, which may indicate a return to the very poor survivals seen at this hatchery through much of its operation (Figure 3). Survival was also much lower than forecast for the wild Toboggan coho.

4.2 Marine Survival Rate Forecast

Survivals for all three northern indicators are expected to fall below the means of their respective time series in 2002 (2001 sea-entry). The forecast for the total return of Lachmach coho was made with the following sibling regression:

$$\log_e(A\ \mathrm{n.1}) = 5.906 + 0.369\log_e(E\ \mathrm{n.0})$$

$$(N = 13;\ \text{adj. } r^2 = 0.52;\ P < 0.005)$$

The estimated jack escapement ($E_{\mathrm{n.0}}$) in 2001 to Lachmach was 229, which leads to a forecast total return of 2.7×10^3, which is also the mean of the available observations (Table 1; 1989 to 2001 returns, Z-score = – 0.01). The 2001 smolt run at Lachmach was estimated to be 20×10^3 leading to a marine survival forecast of 0.075, which is slightly below the mean of 0.100 (Table 1; 1987 to 2000 sea-entry; Z-score = – 0.57). The confidence intervals for the Lachmach survival and abundance forecasts are detailed in Table 2 and in Figure 2.

Very few or no jacks return to interior sites so sibling regression is not possible for either Babine or Toboggan Creek. However, the temporal patterns in marine survival are similar for the three northern indicators (Figure 3), allowing us to use the Lachmach forecast to predict survivals in the two Skeena indicators. The relationship between Lachmach and Toboggan survivals:

$$\operatorname{logit}\left(s_{Toboggan}\right) = 0.933\operatorname{logit}\left(s_{Lachmach}\right) - 1.30$$

$$(N = 14;\ \text{adj. } r^2 = 0.40;\ P < 0.01),$$

gives a forecast survival at Toboggan of 0.026 (50%CI: 0.016 – 0.040; Table 2; Figure 3). That survival is below the mean of the time series (0.039 for the period 1987 to 2000 sea-entry; Z-score = – 0.46). Note that the uncertainty is a minimal estimate because the uncertainty in the forecast of Lachmach survival is not taken in to account.

smolt year	estimated wild smolt number ($\times10^3$)	ratio of wild to hatchery marine survival	estimated wild survival
1995	38	3.895	0.097
1996	35	3.97	0.020
1997	42	3.61	0.067
1998	67	1.15	0.12
1999	44	1.66	0.074
2000	89	0.74	0.061
2001	44	est. 1.18	forecast 0.031

The wild smolt output from Toboggan Creek in 2001 was estimated to have been 44×10^3. The variability of the ratio between observed hatchery and estimated wild survival (see Table below) is large but the ratio appears to be decreasing. If the scalar is set to the average of the last three observations, the wild survival should be around 3.1% and the total wild return would be 1.4×10^3. Assuming an exploitation rate of 36% (i.e., same as 2001), the wild escapement to Toboggan would be 8.7×10^2, including terminal sport fisheries.

That escapement is considerably below the mean of the available observations (2.1×10^3 ; 1988 –2001; *Z*-score = –0.88), but is only slightly below a recently recommended *MSY* escapement target of 900 coho (Shaul and Van Allen 2001).

The relationship between survival of Lachmach and Fort Babine hatchery coho is weaker largely because of the smaller time series and lower than expected survival for the 1995 brood year (Table 1) but is improving as the time series lengthens. The predictive relationship is:

$$\text{logit}\left(s_{Babine}\right) = 1.229\text{logit}\left(s_{Lachmach}\right) - 1.424$$

($N = 8$; adj. $r^2 = 0.48$; $P < 0.05$)

The forecast survival for Babine coho is 0.011, which is below the mean of the time series (0.025, *Z*-score = – 1.05; Table 2; Figure 3). Again note that the uncertainty is a minimal estimate because the uncertainty in the forecast of Lachmach survival is not taken into account.

5. Forecasts of abundance and escapement

5.1 Performance of the 2001 forecasts of abundance

Forecasts of abundance for 2001 were provided for Lachmach, Toboggan wild, the Babine aggregate, and the average-stream index in Statistical Area 6. Forecasts were not provided for the average-stream indices of the other Statistical Areas because escapement data were not available.

Performance of the forecasts can be determined only for the Babine aggregate (Table 5), Lachmach (Table 4), and the average-stream indices in Statistical Area 6 (Table 7). For the Babine aggregate, the total return or stock size as approximately the 97^{th} percentile (S-R model) or the 90^{th} percentile with the 3YRA model. The reason why the forecast was low cannot be determined reliably. Recruits/spawner was a record high for the 1997 brood year (27.5; Table 3). Obviously, survival was well above the mean. Smolt production was extremely high at Toboggan and weather conditions were generally good throughout the area so it is possible that fresh water survival was good. Increased abundance was also seen in other areas (see below), especially to the south of the Skeena so it is possible that marine survival was good. And it is possible that both fresh water and marine survival were strong.

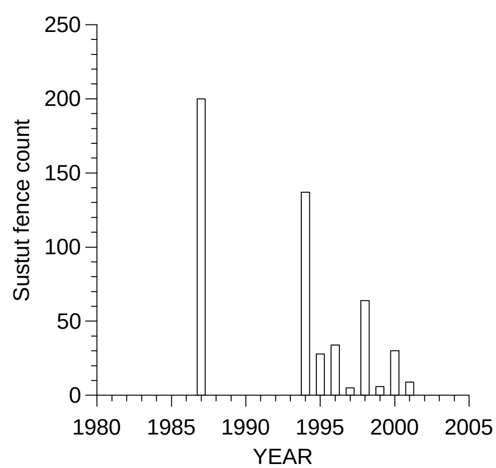
At Lachmach, both total stock size and marine survival fell considerably below their forecast values (Table 4). River flows early in the run of 2000 were high making tag application to the jacks, which appear early, very difficult. Too few tags were applied to jacks in 2000 and their number may have been overestimated (pers. comm. J. Taylor, Sidney BC). Nonetheless, the return in 2001 was well within our expectations for the sibling relationship (Figure 2). Total stock size was considerably under-forecast for the average stream index in Statistical Area 6 (Table 7).

5.2 2002 Abundance forecasts

Forecasts of abundance for the Lachmach wild indicator were presented in an earlier section (Table 2). Forecasts for the Babine Lake aggregate and for the Statistical Area aggregates were made following the same procedures, and are considered together in this section. The following Table summarizes the organization of the forecast Tables and Figures. The Tables show the forecasts for total return (stock size) produced by the S-R and the best of the time series models, which in all but one instance was the three-year average (3YRA). Assuming that the exploitation rate in 2002 will be the same as this year, the forecast escapement is also shown for both models. The Tables also show the forecast escapements as percentages of the $S_{\max}$, the spawner number that on average produces maximum recruitment.

aggregate	preferred model	forecast summary Table	relevant Figure
Babine Lake aggregate	S-R	Table 9	Figure 5
Area 1 (north QCI)	3YRA	Table 10	Figure 6
Area 2W (west QCI)	3YRA	Table 11	Figure 7
Area 2E (east QCI)	3YRA	Table 12	Figure 8
Area 3 (Nass)	S-R	Table 13	Figure 9
Area 4L (middle Skeena)	S-R	Table 14	Figure 10
Area 4C-5 (coastal Skeena & Grenville)	LLY	Table 15	Figure 11
Area 4U (upper Skeena)	S-R	Table 16	Figure 12
Area 6 (Kitimat)	3YRA	Table 17	Figure 13
Area 7 (Bella Bella)	3YRA	Table 18	Figure 14
Area 8 (Bella Coola)	3YRA	Table 19	Figure 15
Area 9/12 (Central Coast)	3YRA	Table 20	Figure 16
Area 13 (Johnstone Strait)	3YRA	Table 21	Figure 17

Table 8 summarizes the results of the Ricker stock-recruitment model fits for the various coho aggregates. The time series for each aggregate are long and have at least an eight-fold range in *S*. However, the properties of these indices of aggregate abundance and their use in stock and recruitment analyses have not been explored. Although the forecast is believed to be conservative, considerable caution must be used in interpreting forecasts based on the stream indices.



The Sustut fence count from 1994 to 2001. The value for 1987 is a visual estimate and is typical of the scattered observations in earlier years.

Table 9 summarizes the forecasts of abundance and escapement for the Babine Lake aggregate. Abundance is forecast to be 2.2×10^4 (50%CI: $1.7 \times 10^4 – 3.0 \times 10^4$) using the preferred S-R model. This return is above the mean of the time series (2.0×10^4; 1946 to 2001; *Z*-score = 0.26). Assuming an exploitation rate of 0.55, escapement would be 9.4×10^3, which is above the mean of the time series (7.9×10^3; 1946 to 2001; *Z*-score = 0.29) and approximately 78% of the provisional escapement target for the aggregate (1.2×10^4; Holtby et al. 1999b). Increases in Canadian exploitation rate to 15% (D. Peacock, DFO, Prince Rupert; it was 10% in 2001) are unlikely to pose significant risk to this aggregate in isolation. However, survival appears to be falling after several years of values well above the long-term mean. In addition, small coho populations in the 'High Interior' (Skeena Plateau) (e.g. the Sustut, see graph to right) have not recovered with the vigor that Babine aggregate has, presumably because of lower productivity. Those populations may be vulnerable to increased exploitation at this time. We would recommend that the Canadian exploitation rate not be increased in 2002. However, Alaskan biologists have recently argued that the escapement target for the Babine aggregate should be no more than 4,000 and could be as low as 1,900 (Shaul and Van Allen 2001), in which case Canadian fisheries could conservatively expand to approximately 37% (total exploitation rate of 81%). Such a high rate might pose some risk to less productive populations in the upper Skeena.

The following Table summarizes the forecasts of abundance and escapement for the aggregates. We have arranged the aggregates into six geographical groups based on geography, distributions of CWT's in fisheries and on productivity (Holtby et al. 1999b). This is a convenient way to summarize the forecasts because forecasts of abundance and escapement for average stream indices are useful only in the context of how far they deviate from the long-term means of their respective time series.

Forecast characterizations for the aggregates considered. Probability values between 35% and 65% were characterized as average; probabilities less than 15% or greater than 85% were characterized as either well below or well above average respectively. See the text for an explanation of the groups.

			total return (abundance)		escapement		
aggregate	group	model	forecast *P* †	characterization	forecast *P*	characterization	% of S_{max}
Area 2W	1	3YRA	35%	average	56%	average	43%
Area 1	2	3YRA	38%	average	70%	above average	97%
Area 3	2	S-R	71%	above average	90%	well above average	96%
Area 4L	3	S-R	54%	average	90%	well above average	111%
Area 4U	3	S-R	73%	above average	85%	well above average	125%
Babine Lake aggregate	3	S-R	63%	above average	75%	above average	85%
Area 2E	4	3YRA	11%	well below average	46%	average	31%
Area 4C/Area 5	4	LLY	5%	well below average	25%	below average	40%
Area 6	4	3YRA	23%	below average	55%	average	36%
Area 7	4	3YRA	29%	below average	62%	average	65%
Area 8	5	3YRA	11%	well below average	43%	average	43%
Area 9/12	5	3YRA	38%	average	78%	above average	55%
Area 13	6	3YRA	4%	well below average	28%	below average	13%

† Proportions of observed abundance or escapement less than the forecast value. These calculations assume a log-normal cumulative probability distribution with mean and standard deviation calculated over the observation period 1950 (1946 for Babine) to 2001 (return years).

The forecast abundance of Skeena and Nass aggregates, including the Babine and the upper Skeena, and the northern and western portions of the Queen Charlotte Islands can be characterized as average or better abundance and above average or better escapements. These groups include the most productive of the aggregates in the northern and central coastal areas and the coho in these areas have responded strongly to reduced fishing pressure and several years of above-mean marine and fresh water survival. The only caveat on these forecasts is the continued weakness in some of the high interior populations of the upper Skeena typified by the Sustut River escapement indicator. Their weakness may be related to low productivity and continued fishing pressure in a continuation of the classical mixed-stock fishery problem that led to many of the past problems in the upper Skeena.

The forecast for the aggregates around Hecate Strait is poorer than the Skeena and Nass aggregates to the north. These aggregates are on the whole likely the least productive in the region and forecast abundance is no better than below-average. However, with continued restrictions to fisheries, i.e., no increases over 2001 levels of exploitation, escapement is forecast to be average except in Area 4C/5. However, information is very limited in this particular Statistical Area. In this Area and at current levels of exploitation the forecast escapement is at a level of 40% of S_{max}. Typically S_{max} is between 55% and 75% of S_{MSY} so escapements that are 30% of S_{max} are at worst approximately 55% of S_{MSY} and do not represent a conservation concern.

6. Conclusions

6.1 Marine survival

In 2002, marine survival at the three northern indicators is expected to be below the means over their respective periods of observation.

indicator	model	$\hat{s}_{2002}$	(50% CI)	observed mean and period of observation (year of sea-entry)	
Lachmach	sibling regression	0.075	(0.06–0.09)	0.10	(1987 – 2000)
Toboggan Creek hatchery	from Lachmach	0.025	(0.016–0.04)	0.039	(1987 – 2000)
Fort Babine hatchery	from Lachmach	0.011	(0.007–0.02)	0.025	(1993 – 2000)

The period of observation is short for all three indicators. The survival rate of wild Toboggan Creek coho should be comparable to Lachmach but cannot be reliably forecast.

6.2 Abundance forecast

Estimated smolt production from Lachmach in 2001 was 3.6×10^4, which is slightly above the observed mean of 3.1×10^4 (1987 – 2000). That combined with below-mean marine survival produce a forecast return of 2.7×10^3 (50%CI: 2.2×10^3 – 3.3×10^3) which is the mean of 2.7×10^3 observed over the period 1988 to 2001 (return years). Wild smolt production from Toboggan Creek in 2001 was estimated to have been 44×10^3. When combined with a forecast of below-mean marine survival the forecast of total wild return is 1.4×10^3, which is considerably less than the mean total return of 4.7×10^3 (return years 1988 – 2001). Assuming an exploitation rate of 36% (i.e., same as 2001), the wild escapement to Toboggan would be 8.7×10^2, including terminal sport fisheries. That escapement is considerably below the mean of the available observations (2.1×10^3; 1988 –2001; Z-score = –0.88), but is only slightly below a recently recommended *MSY* escapement target of 900 (Shaul and Van Allen 2001). Abundance of Babine Lake coho is forecast to be 2.2×10^4 (50%CI: 1.7×10^4 – 3.0×10^4) using the preferred S-R model. This return is above the mean of the time series (1.2×10^4; 1946 to 2001; Z-score = 1.02). Assuming an exploitation rate of 0.55, escapement would be 9.4×10^3, which is approximately 78% of the provisional escapement target for the aggregate (1.2×10^4).

The stock-recruit and time series forecasts of abundance for Babine coho and the average-stream indices of the 12 north and central coastal aggregates show some indication of geographic patterning but do not indicate any conservation concerns in the area, with the possible exceptions of Area 4C/5 and Area 13. Unfortunately, escapement data are very poor in Area 4C/5 so it is difficult to determine the extent to which the poor escapements are due simply to limited data. Escapement data are better in Area 13 and there are other indications including fresh water juvenile surveys that are consistent with the poor status indicated by the escapement index. The total abundance and the escapement of coho in the northern part of the forecast region (Areas 1, 3, 4L and 4U) will average to above-average in 2002. In the areas around Hecate Strait (Areas 2E, 4C/5, 6 to 12), total abundance will be well below average to average but provided fisheries do not expand much over levels in 2001, escapements will be average in most of those areas. Forecast abundance in Johnston Strait streams (Area 13) can be characterized as well below the mean. Without further investigation of this situation and a demonstration that status is actually better than indicated by the index used here, expansion of fisheries in the part of the coast should be discouraged.

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Table 1. Marine survival rate estimates at three northern BC coho indicators. Toboggan and Fort Babine are hatchery indicators. Lachmach is a wild indicator. The stock size for Toboggan Creek is the wild component only.

	marine survival rates			total stock size	
return year	Lachmach	Toboggan	Fort Babine	Lachmach	Toboggan
1988	0.030	0.021		2,146	1,689
1989	0.044	0.027		1,590	5,498
1990	0.113	0.041		4,116	8,842
1991	0.121	0.060		4,194	8,125
1992	0.088	0.017		1,679	5,897
1993	0.061	0.028		2,065	3,638
1994	0.174	0.060	0.040	4,570	5,779
1995	0.082	0.018	0.010	3,223	2,736
1996	0.072	0.025	0.031	3,925	3,708
1997	0.055	0.005	0.006	1,728	691
1998	0.096	0.018	0.007	2,025	2,823
1999	0.125	0.104	0.051	2,437	7,872
2000	0.144	0.044	0.018	1,960	3,479
2001	0.136	0.083	0.033	2,733	5,491

Table 2. Forecasts of 2001 sea-entry (2002 return) marine survival for three northern BC coho indicators and abundance for the Lachmach River, with associated confidence intervals. '*A*' is total abundance while '*s*' is marine survival.

	Lachmach		Toboggan	Fort Babine
probability of smaller return or survival	$\hat{A}_{2002}$	$\hat{s}_{2002}$	$\hat{s}_{2002}$	$\hat{s}_{2002}$
99%	5.8E+03	0.16	0.13	0.078
95%	4.5E+03	0.12	0.077	0.037
90%	4.0E+03	0.11	0.060	0.027
75%	3.3E+03	0.091	0.040	0.017
50%	**2.7E+03**	**0.075**	**0.026**	**0.011**
25%	2.2E+03	0.062	0.016	0.007
10%	1.9E+03	0.052	0.011	0.004
5%	1.7E+03	0.046	0.008	0.003
1%	1.3E+03	0.035	0.005	0.001

Table 3. Stock-recruit data for the Babine coho aggregate.

brood year	total escapement	exploitation rate	proportion age 3	R/S
1946	13411	0.55	0.65	1.895
1947	10815	0.55	0.65	3.441
1948	13734	0.55	0.65	2.473
1949	12961	0.55	0.52	1.521
1950	11654	0.55	0.59	0.950
1951	2276	0.55	0.51	6.400
1952	10554	0.55	0.53	1.887
1953	7655	0.55	0.57	2.199
1954	3359	0.55	0.80	4.366
1955	9714	0.55	0.60	2.236
1956	9857	0.55	0.67	2.096
1957	4421	0.55	0.78	5.480
1958	8438	0.55	0.62	4.218
1959	12004	0.55	0.62	1.989
1960	7942	0.55	0.75	3.117
1961	14416	0.55	0.65	2.602
1962	15183	0.55	0.56	2.084
1963	7737	0.50	0.67	4.064
1964	10689	0.63	0.49	3.465
1965	22985	0.48	0.47	0.649
1966	13377	0.59	0.67	1.343
1967	12487	0.47	0.59	1.915
1968	13054	0.59	0.27	1.296
1969	6702	0.50	0.52	3.039
1970	10404	0.57	0.55	2.243
1971	9909	0.57	0.53	2.602
1972	5381	0.66	0.70	1.631
1973	11606	0.51	0.60	1.608
1974	13661	0.56	0.71	1.462
1975	4913	0.46	0.60	6.468
1976	4499	0.46	0.60	2.668
1977	10474	0.59	0.46	1.894
1978	11861	0.69	0.78	0.339
1979	2909	0.71	0.77	3.296
1980	5046	0.74	0.78	3.599
1981	2486	0.67	0.36	3.006
1982	2673	0.58	0.79	4.229
1983	3402	0.81	0.74	5.193
1984	3241	0.72	0.54	2.128
1985	2129	0.75	0.85	4.999
1986	3671	0.83	0.81	4.483
1987	2101	0.64	0.90	10.37
1988	3225	0.63	0.81	5.609
1989	5228	0.67	0.77	1.222
1990	5619	0.74	0.81	2.355
1991	4941	0.77	0.78	5.021
1992	1714	0.70	0.73	9.495
1993	2186	0.72	0.72	3.084
1994	4053	0.86	0.74	0.717
1995	2345	0.87	0.81	6.080
1996	2669	0.67	0.80	8.471
1997	453	0.55	0.76	27.491
1998	4291	0.60	0.80	7.284

brood year	total escapement	exploitation rate	proportion age 3	R/S
1999	14908	0.46	0.79	
2000	2235	0.57	0.84	
2001	21618	0.35	0.76	

Table 4. Performance of the 2001 forecast total return and marine survival for the Lachmach River wild indicator. The forecasts are based on a sibling regression model.

	total return		marine survival	
probability of a lower value	observed	2001 forecast	observed	2001 forecast
99%		7.7×10^3		0.64
95%		5.9×10^3		0.48
90%		5.2×10^3		0.43
75%		4.2×10^3		0.35
50%	**2.7×10^3**	**3.5×10^3**	**0.135**	**0.29**
25%		2.8×10^3		0.23
10%		2.3×10^3		0.19
5%		2.0×10^3		0.17
1%		1.5×10^3		0.13

Table 5. Performance of the 2001 forecast total return for the Babine Lake coho aggregate. Stock-recruitment and time series models were used to forecast in 2000. The preferred model is underlined.

	total return		
	observed	2001 forecast	
probability of a lower value		<u>S-R</u>	3YRA
99%		5.8E+04	1.4E+05
95%		3.6E+04	6.4E+04
90%		2.9E+04	4.3E+04
75%		2.1E+04	2.3E+04
50%	**3.34E+04**	**1.4E+04**	**1.1E+04**
25%		1.0E+04	5.6E+03
10%		7.4E+03	3.0E+03
5%		6.1E+03	2.0E+03
1%		4.2E+03	9.4E+02

Table 6. Performance of the 2001 forecasts of marine survival for Toboggan Creek and Fort Babine hatcheries.

	Toboggan Creek		Fort Babine	
probability of a lower value	observed	2001 forecast	observed	2001 forecast
99%		0.45		0.65
95%		0.28		0.35
90%		0.22		0.25
75%		0.14		0.15
50%	**0.08**	**0.09**	**0.011**	**0.08**
25%		0.05		0.04
10%		0.03		0.02
5%		0.02		0.01
1%		0.01		0.004

Table 7. Performance of the 2001 forecast total return for the Area 6 aggregate. Stock-recruitment and time series models were used to forecast in 2001. The preferred model is underlined.

probability of a lower value	total return		
	observed	2001 forecast	
		S-R	<u>3YRA</u>
99%		3.2E+03	2.8E+03
95%		2.4E+03	1.9E+03
90%		2.1E+03	1.6E+03
75%		1.7E+03	1.2E+03
50%	**2.8E+03**	**1.4E+03**	**8.4E+02**
25%		1.2E+03	6.0E+02
10%		9.9E+02	4.4E+02
5%		9.0E+02	3.7E+02
1%		7.7E+02	2.5E+02

Table 8. Summary of the Ricker stock-recruitment analyses on reconstructed time series for the Babine Lake and the Statistical Area aggregates.

aggregate	Ricker stock-recruitment analysis						
	N	adj. r^2	a’	b’	S_{MSY}	S_{MAX}[§]	u_{MSY}
Area 1	49	0.54	2.025	7454	2670	3681	0.73
Area 2W	49	0.37	1.77	670	252	378	0.67
Area 2E	49	0.31	1.38	2306	931	1677	0.56
Area 3	49	0.26	1.88	3778	1392	2008	0.69
Area 4L	49	0.38	1.85	2493	924	1349	0.68
Area 4U	49	0.33	2.03	1637	586	808	0.73
Babine Lake aggregate	52	0.44	2.02	19005	6821	9430	0.72
Area 4C/Area 5	49	0.44	1.87	1918	707	1024	0.69
Area 6	49	0.36	1.42	2712	1085	1903	0.57
Area 7	49	0.47	1.77	942	354	531	0.67
Area 8	49	0.38	1.64	5765	2219	3506	0.63
Area 9/12	49	0.29	1.42	4043	1619	2842	0.57
Area 13	46	0.10	1.392	3923	1579	2819	0.56

[§] The spawner number producing on average the maximum recruitment..

Table 9. For the Babine Lake aggregate, 2002 forecasts and associated confidence intervals for total return, escapement and proportion of S_{max} from the Stock-Recruitment (S-R) and time series (3YRA) models. *Z*-scores for the forecasts of total return and escapement are also given. An exploitation rate of 0.51 was assumed. The S-R model is the preferred model.

P[§]	forecast total return				forecast escapement				proportion of Smax	
	S-R	z-score	3YRA	z-score	S-R	z-score	3YRA	z-score	S-R	3YRA
99%	7.5E+04	5.35	1.1E+05	8.24	3.7E+04	5.66	5.2E+04	8.51	328%	7.5E+04
95%	4.8E+04	2.70	6.0E+04	3.87	2.4E+04	3.04	3.0E+04	4.20	208%	4.8E+04
90%	3.9E+04	1.84	4.5E+04	2.42	1.9E+04	2.19	2.2E+04	2.76	170%	3.9E+04
75%	2.8E+04	0.81	2.8E+04	0.78	1.4E+04	1.18	1.4E+04	1.15	124%	2.8E+04
50%	**2.1E+04**	**0.09**	**1.7E+04**	**-0.31**	**1.0E+04**	**0.46**	**8.2E+03**	**0.07**	**91%**	**2.1E+04**
25%	1.6E+04	-0.40	1.0E+04	-0.96	7.8E+03	-0.02	4.9E+03	-0.57	69%	1.6E+04
10%	1.3E+04	-0.72	6.2E+03	-1.33	6.2E+03	-0.33	3.1E+03	-0.93	54%	1.3E+04
5%	1.1E+04	-0.87	4.7E+03	-1.48	5.4E+03	-0.48	2.3E+03	-1.08	48%	1.1E+04
1%	8.8E+03	-1.08	2.7E+03	-1.67	4.3E+03	-0.69	1.3E+03	-1.27	38%	8.8E+03

[§]probability of a lower value

Table 10. For the Area 1 aggregate, 2002 forecasts and associated confidence intervals for total return, escapement and proportion of S_{max} from the Stock-Recruitment (S-R) and time series (3YRA) models. *Z*-scores for the forecasts of total return and escapement are also given. An exploitation rate of 0.29 was assumed. The 3YRA is the preferred model.

P[§]	forecast total return				forecast escapement				proportion of Smax	
	S-R	z-score	3YRA	z-score	S-R	z-score	3YRA	z-score	S-R	3YRA
99%	2.2E+0	2.80	2.7E+0	3.94	1.4E+0	5.82	1.8E+0	7.71	326%	404%
95%	1.6E+0	1.46	1.8E+0	1.87	1.0E+0	3.61	1.2E+0	4.28	233%	261%
90%	1.4E+0	0.99	1.4E+0	1.10	8.9E+0	2.84	9.2E+0	3.02	201%	209%
75%	1.1E+0	0.41	9.8E+0	0.17	7.1E+0	1.86	6.4E+0	1.47	161%	145%
50%	8.8E+0	-0.04	6.6E+0	-0.52	5.8E+0	1.12	4.3E+0	0.32	130%	97%
25%	7.3E+0	-0.37	4.4E+0	-0.99	4.8E+0	0.58	2.9E+0	-0.45	108%	65%
10%	6.2E+0	-0.59	3.1E+0	-1.28	4.1E+0	0.21	2.0E+0	-0.93	92%	45%
5%	5.7E+0	-0.70	2.4E+0	-1.41	3.7E+0	0.03	1.6E+0	-1.14	85%	36%
1%	4.9E+0	-0.88	1.6E+0	-1.59	3.2E+0	-0.26	1.0E+0	-1.45	73%	23%

[§]probability of a lower value

Table 11. For the Area 2W aggregate, 2002 forecasts and associated confidence intervals for total return, escapement and proportion of S_{max} from the Stock-Recruitment (S-R) and time series (3YRA) models. *Z*-scores for the forecasts of total return and escapement are also given. An exploitation rate of 0.29 was assumed. The 3YRA is the preferred model.

$P^{§}$	forecast total return				forecast escapement				proportion of Smax	
	S-R	z-score	3YRA	z-score	S-R	z-score	3YRA	z-score	S-R	3YRA
99%	2.3E+03	4.06	2.0E+03	3.33	1.5E+03	6.25	1.3E+03	5.24	326%	282%
95%	1.4E+03	1.92	1.1E+03	1.30	8.9E+02	3.28	7.2E+02	2.42	197%	159%
90%	1.1E+03	1.27	8.2E+02	0.62	7.1E+02	2.39	5.4E+02	1.49	158%	118%
75%	7.9E+02	0.55	5.1E+02	-0.13	5.2E+02	1.39	3.3E+02	0.45	114%	73%
50%	**5.9E+02**	**0.07**	**3.0E+02**	**-0.62**	**3.9E+02**	**0.72**	**2.0E+02**	**-0.23**	**85%**	**43%**
25%	4.7E+02	-0.23	1.8E+02	-0.92	3.0E+02	0.31	1.2E+02	-0.64	67%	26%
10%	3.9E+02	-0.41	1.1E+02	-1.08	2.5E+02	0.06	7.1E+01	-0.86	56%	16%
5%	3.6E+02	-0.49	8.2E+01	-1.14	2.3E+02	-0.05	5.3E+01	-0.96	51%	12%
1%	3.1E+02	-0.60	4.6E+01	-1.23	2.0E+02	-0.20	3.0E+01	-1.07	45%	7%

§probability of a lower value

Table 12. For the Area 2E aggregate, 2002 forecasts and associated confidence intervals for total return, escapement and proportion of S_{max} from the Stock-Recruitment (S-R) and time series (3YRA) models. *Z*-scores for the forecasts of total return and escapement are also given. An exploitation rate of 0.29 was assumed. The 3YRA is the preferred model.

$P^{§}$	forecast total return				forecast escapement				proportion of Smax	
	S-R	z-score	3YRA	z-score	S-R	z-score	3YRA	z-score	S-R	3YRA
99%	4.0E+0	2.78	2.2E+0	0.53	2.9E+0	5.41	1.5E+0	2.03	144%	77%
95%	3.0E+0	1.56	1.6E+0	-0.11	2.2E+0	3.57	1.2E+0	1.07	107%	58%
90%	2.6E+0	1.10	1.4E+0	-0.37	1.9E+0	2.88	1.0E+0	0.67	94%	50%
75%	2.1E+0	0.48	1.1E+0	-0.73	1.5E+0	1.96	8.0E+0	0.14	76%	40%
50%	**1.7E+0**	**-0.02**	**8.6E+0**	**-1.04**	**1.2E+0**	**1.20**	**6.2E+0**	**-0.32**	**61%**	**31%**
25%	1.4E+0	-0.42	6.6E+0	-1.27	9.8E+0	0.61	4.8E+0	-0.67	49%	24%
10%	1.1E+0	-0.72	5.2E+0	-1.44	8.1E+0	0.16	3.7E+0	-0.92	40%	19%
5%	1.0E+0	-0.87	4.5E+0	-1.52	7.1E+0	-0.07	3.2E+0	-1.05	35%	16%
1%	7.8E+0	-1.13	3.4E+0	-1.66	5.6E+0	-0.46	2.4E+0	-1.25	28%	12%

§probability of a lower value

Table 13. For the Area 3 aggregate,2002 forecasts and associated confidence intervals for total return, escapement and proportion of S_{max} from the Stock-Recruitment (S-R) and time series (3YRA) models. *Z*-scores for the forecasts of total return and escapement are also given. An exploitation rate of 0.51 was assumed. The S-R is the preferred model.

P§	forecast total return				forecast escapement				proportion of Smax	
	S-R	z-score	3YRA	z-score	S-R	z-score	3YRA	z-score	S-R	3YRA
99%	1.2E+	2.42	1.4E+	2.96	6.1E+	7.18	7.0E+	8.57	254%	292%
95%	8.7E+	1.32	9.5E+	1.55	4.3E+	4.35	4.7E+	4.96	177%	193%
90%	7.4E+	0.95	7.7E+	1.03	3.6E+	3.41	3.8E+	3.60	151%	156%
75%	5.9E+	0.50	5.4E+	0.37	2.9E+	2.27	2.7E+	1.93	119%	110%
50%	**4.7E+**	**0.18**	**3.7E+**	**-0.12**	**2.3E+**	**1.43**	**1.8E+**	**0.66**	**96%**	**75%**
25%	3.9E+	-0.05	2.5E+	-0.46	1.9E+	0.84	1.2E+	-0.20	80%	51%
10%	3.4E+	-0.20	1.8E+	-0.67	1.7E+	0.46	8.7E+	-0.76	69%	36%
5%	3.2E+	-0.27	1.4E+	-0.77	1.6E+	0.27	7.0E+	-1.01	64%	29%
1%	2.8E+	-0.38	9.5E+	-0.91	1.4E+	0.00	4.7E+	-1.37	57%	19%

§probability of a lower value

Table 14. For the Area 4L aggregate, 2002 forecasts and associated confidence intervals for total return, escapement and proportion of S_{max} from the Stock-Recruitment (S-R) and time series (3YRA) models. *Z*-scores for the forecasts of total return and escapement are also given. An exploitation rate of 0.31 was assumed. The S-R is the preferred model.

P§	forecast total return				forecast escapement				proportion of Smax	
	S-R	z-score	3YRA	z-score	S-R	z-score	3YRA	z-score	S-R	3YRA
99%	6.8E+	2.44	8.5E+	3.44	4.9E+	7.54	6.1E+	9.91	302%	376%
95%	4.8E+	1.21	5.4E+	1.56	3.4E+	4.64	3.8E+	5.47	210%	237%
90%	4.1E+	0.78	4.2E+	0.88	2.9E+	3.64	3.0E+	3.87	179%	186%
75%	3.2E+	0.26	2.9E+	0.07	2.3E+	2.40	2.0E+	1.95	140%	126%
50%	**2.5E+**	**-0.14**	**1.9E+**	**-0.53**	**1.8E+**	**1.47**	**1.3E+**	**0.56**	**111%**	**82%**
25%	2.0E+	-0.42	1.2E+	-0.91	1.5E+	0.81	8.7E+	-0.36	90%	54%
10%	1.7E+	-0.61	8.3E+	-1.15	1.2E+	0.35	5.9E+	-0.91	76%	36%
5%	1.6E+	-0.70	6.5E+	-1.25	1.1E+	0.14	4.7E+	-1.16	69%	29%
1%	1.3E+	-0.85	4.1E+	-1.40	9.5E+	-0.20	2.9E+	-1.50	59%	18%

§probability of a lower value

Table 15. For the Area 4C-5 aggregate, 2002 forecasts and associated confidence intervals for total return, escapement and proportion of S_{max} from the Stock-Recruitment (S-R) and time series (3YRA) models. *Z*-scores for the forecasts of total return and escapement are also given. An exploitation rate of 0.29 was assumed. The LLY is the preferred model.

P§	forecast total return				forecast escapement				proportion of Smax	
	S-R	z-score	LLY	z-score	S-R	z-score	LLY	z-score	S-R	LLY
99%	5.7E+	3.26	2.7E+	0.59	4.1E+	6.46	1.9E+	2.14	331%	157%
95%	3.6E+	1.43	1.8E+	-0.23	2.6E+	3.49	1.3E+	0.81	212%	103%
90%	3.0E+	0.82	1.4E+	-0.54	2.1E+	2.51	1.0E+	0.31	172%	83%
75%	2.1E+	0.09	1.0E+	-0.92	1.5E+	1.34	7.2E+	-0.30	125%	59%
50%	**1.6E+**	**-0.43**	**6.9E+**	**-1.20**	**1.1E+**	**0.48**	**4.9E+**	**-0.76**	**90%**	**40%**
25%	1.1E+	-0.79	4.7E+	-1.40	8.2E+	-0.10	3.3E+	-1.08	67%	27%
10%	8.8E+	-1.03	3.3E+	-1.52	6.3E+	-0.49	2.3E+	-1.28	51%	19%
5%	7.6E+	-1.14	2.6E+	-1.58	5.4E+	-0.66	1.9E+	-1.37	44%	15%
1%	5.7E+	-1.31	1.7E+	-1.66	4.1E+	-0.93	1.2E+	-1.50	33%	10%

§probability of a lower value

Table 16. For the Area 4U aggregate, 2002 forecasts and associated confidence intervals for total return, escapement and proportion of S_{max} from the Stock-Recruitment (S-R) and time series (3YRA) models. *Z*-scores for the forecasts of total return and escapement are also given. An exploitation rate of 0.42 was assumed. The S-R is the preferred model.

P§	forecast total return				forecast escapement				proportion of Smax	
	S-R	z-score	3YRA	z-score	S-R	z-score	3YRA	z-score	S-R	3YRA
99%	7.4E+	5.73	8.8E+	7.08	4.3E+	8.74	5.1E+	10.63	447%	530%
95%	4.5E+	2.84	4.8E+	3.15	2.6E+	4.69	2.8E+	5.12	270%	289%
90%	3.6E+	1.99	3.5E+	1.88	2.1E+	3.50	2.1E+	3.34	218%	212%
75%	2.7E+	1.06	2.1E+	0.50	1.6E+	2.19	1.2E+	1.40	161%	127%
50%	**2.1E+**	**0.46**	**1.2E+**	**-0.39**	**1.2E+**	**1.35**	**7.1E+**	**0.16**	**125%**	**73%**
25%	1.7E+	0.10	6.9E+	-0.90	9.9E+	0.84	4.0E+	-0.55	102%	42%
10%	1.5E+	-0.12	4.2E+	-1.17	8.7E+	0.54	2.4E+	-0.93	89%	25%
5%	1.4E+	-0.21	3.1E+	-1.28	8.1E+	0.41	1.8E+	-1.09	84%	18%
1%	1.3E+	-0.33	1.7E+	-1.41	7.4E+	0.24	9.7E+	-1.28	76%	10%

§probability of a lower value

Table 17. For the Area 6 aggregate, 2002 forecasts and associated confidence intervals for total return, escapement and proportion of S_{max} from the Stock-Recruitment (S-R) and time series (3YRA) models. *Z*-scores for the forecasts of total return and escapement are also given. An exploitation rate of 0.29 was assumed. The 3YRA is the preferred model.

P[§]	forecast total return				forecast escapement				proportion of Smax	
	S-R	z-score	3YRA	z-score	S-R	z-score	3YRA	z-score	S-R	3YRA
99%	3.2E+	0.96	4.1E+	1.78	2.3E+	2.40	2.9E+	3.53	101%	129%
95%	2.6E+	0.40	2.8E+	0.59	1.9E+	1.62	2.0E+	1.88	81%	88%
90%	2.4E+	0.20	2.3E+	0.14	1.7E+	1.33	1.6E+	1.25	74%	72%
75%	2.1E+	-0.07	1.7E+	-0.44	1.5E+	0.96	1.2E+	0.45	65%	52%
50%	**1.8E+**	**-0.29**	**1.2E+**	**-0.88**	**1.3E+**	**0.66**	**8.3E+**	**-0.17**	**57%**	**36%**
25%	1.6E+	-0.45	8.1E+	-1.19	1.2E+	0.43	5.8E+	-0.61	51%	25%
10%	1.5E+	-0.57	5.9E+	-1.40	1.1E+	0.26	4.2E+	-0.89	47%	18%
5%	1.4E+	-0.63	4.8E+	-1.49	1.0E+	0.18	3.4E+	-1.03	45%	15%
1%	1.3E+	-0.73	3.3E+	-1.63	9.5E+	0.04	2.3E+	-1.22	42%	10%

[§]probability of a lower value

Table 18. For the Area 7 aggregate, 2002 forecasts and associated confidence intervals for total return, escapement and proportion of S_{max} from the Stock-Recruitment (S-R) and time series (3YRA) models. *Z*-scores for the forecasts of total return and escapement are also given. An exploitation rate of 0.29 was assumed. The 3YRA is the preferred model.

P[§]	forecast total return				forecast escapement				proportion of Smax	
	S-R	z-score	3YRA	z-score	S-R	z-score	3YRA	z-score	S-R	3YRA
99%	2.6E+	3.12	2.0E+	2.06	1.8E+	6.01	1.4E+	4.34	289%	226%
95%	1.8E+	1.59	1.4E+	0.84	1.3E+	3.59	9.8E+	2.41	198%	154%
90%	1.5E+	1.06	1.1E+	0.37	1.1E+	2.75	8.1E+	1.66	167%	127%
75%	1.1E+	0.40	8.2E+	-0.22	8.2E+	1.71	5.9E+	0.73	128%	92%
50%	**8.8E+**	**-0.10**	**5.8E+**	**-0.69**	**6.3E+**	**0.92**	**4.1E+**	**0.00**	**99%**	**65%**
25%	7.0E+	-0.46	4.0E+	-1.01	5.0E+	0.36	2.9E+	-0.52	78%	45%
10%	5.7E+	-0.70	2.9E+	-1.23	4.0E+	-0.03	2.1E+	-0.85	63%	33%
5%	5.0E+	-0.82	2.4E+	-1.33	3.6E+	-0.22	1.7E+	-1.01	57%	27%
1%	4.1E+	-1.01	1.6E+	-1.47	2.9E+	-0.51	1.2E+	-1.24	46%	18%

[§]probability of a lower value

Table 19. For the Area 8 aggregate, 2002 forecasts and associated confidence intervals for total return, escapement and proportion of S_{max} from the Stock-Recruitment (S-R) and time series (3YRA) models. *Z*-scores for the forecasts of total return and escapement are also given. An exploitation rate of 0.29 was assumed. The 3YRA is the preferred model.

P§	forecast total return				forecast escapement				proportion of Smax	
	S-R	z-score	3YRA	z-score	S-R	z-score	3YRA	z-score	S-R	3YRA
99%	1.3E	2.95	9.2E	1.45	9.4E	5.77	6.6E	3.48	224%	157%
95%	9.2E	1.42	6.2E	0.30	6.5E	3.43	4.4E	1.71	156%	105%
90%	7.7E	0.89	5.1E	-0.13	5.5E	2.61	3.6E	1.04	132%	86%
75%	6.0E	0.21	3.6E	-0.68	4.3E	1.57	2.6E	0.21	101%	61%
50%	**4.6E**	**-0.31**	**2.5E**	**-1.10**	**3.3E**	**0.77**	**1.8E**	**-0.44**	**78%**	**43%**
25%	3.6E	-0.70	1.7E	-1.39	2.5E	0.18	1.2E	-0.89	61%	29%
10%	2.9E	-0.97	1.2E	-1.58	2.0E	-0.23	8.9E	-1.17	49%	21%
5%	2.5E	-1.10	1.0E	-1.67	1.8E	-0.43	7.2E	-1.31	43%	17%
1%	2.0E	-1.31	6.8E	-1.79	1.4E	-0.76	4.8E	-1.50	33%	12%

§probability of a lower value

Table 20. For the Area 9/12 aggregate, 2002 forecasts and associated confidence intervals for total return, escapement and proportion of S_{max} from the Stock-Recruitment (S-R) and time series (3YRA) models. *Z*-scores for the forecasts of total return and escapement are also given. An exploitation rate of 0.29 was assumed. The 3YRA is the preferred model.

P§	forecast total return				forecast escapement				proportion of Smax	
	S-R	z-score	3YRA	z-score	S-R	z-score	3YRA	z-score	S-R	3YRA
99%	1.1E+	4.34	8.1E+	2.72	8.8E+	8.52	6.5E+	5.85	258%	190%
95%	7.4E+	2.34	5.6E+	1.30	5.9E+	5.22	4.4E+	3.50	174%	130%
90%	6.2E+	1.65	4.6E+	0.75	4.9E+	4.08	3.7E+	2.60	145%	107%
75%	4.6E+	0.78	3.3E+	0.05	3.7E+	2.65	2.7E+	1.45	109%	78%
50%	**3.5E+**	**0.13**	**2.3E+**	**-0.49**	**2.8E+**	**1.57**	**1.9E+**	**0.55**	**81%**	**55%**
25%	2.6E+	-0.35	1.7E+	-0.88	2.1E+	0.78	1.3E+	-0.09	61%	39%
10%	2.0E+	-0.67	1.2E+	-1.13	1.6E+	0.24	9.7E+	-0.51	47%	28%
5%	1.7E+	-0.83	9.9E+	-1.25	1.4E+	-0.02	8.0E+	-0.70	41%	23%
1%	1.3E+	-1.08	6.8E+	-1.42	1.0E+	-0.43	5.5E+	-0.99	30%	16%

§probability of a lower value

Table 21. For the Area 13 aggregate, 2002 forecasts and associated confidence intervals for total return, escapement and proportion of S_{max} from the Stock-Recruitment (S-R) and time series (3YRA) models. *Z*-scores for the forecasts of total return and escapement are also given. An exploitation rate of 0.05 was assumed. The 3YRA is the preferred model.

$P^{§}$	forecast total return				forecast escapement				proportion of Smax	
	S-R	z-score	3YRA	z-score	S-R	z-score	3YRA	z-score	S-R	3YRA
99%	4.1E+03	1.37	1.5E+03	-0.47	3.9E+03	5.79	1.4E+03	1.23	115%	43%
95%	2.6E+03	0.32	1.1E+03	-0.80	2.5E+03	3.19	1.0E+03	0.40	74%	30%
90%	2.1E+03	-0.03	8.8E+02	-0.93	2.0E+03	2.32	8.3E+02	0.08	60%	25%
75%	1.5E+03	-0.46	6.5E+02	-1.09	1.5E+03	1.25	6.1E+02	-0.33	43%	18%
50%	**1.1E+03**	**-0.77**	**4.6E+02**	**-1.23**	**1.0E+03**	**0.48**	**4.4E+02**	**-0.66**	**31%**	**13%**
25%	8.0E+02	-0.99	3.3E+02	-1.32	7.6E+02	-0.07	3.1E+02	-0.89	22%	9%
10%	6.0E+02	-1.13	2.4E+02	-1.38	5.6E+02	-0.43	2.3E+02	-1.05	17%	7%
5%	5.0E+02	-1.20	2.0E+02	-1.41	4.7E+02	-0.60	1.9E+02	-1.12	14%	6%
1%	3.5E+02	-1.31	1.4E+02	-1.46	3.3E+02	-0.86	1.3E+02	-1.23	10%	4%

§probability of a lower value

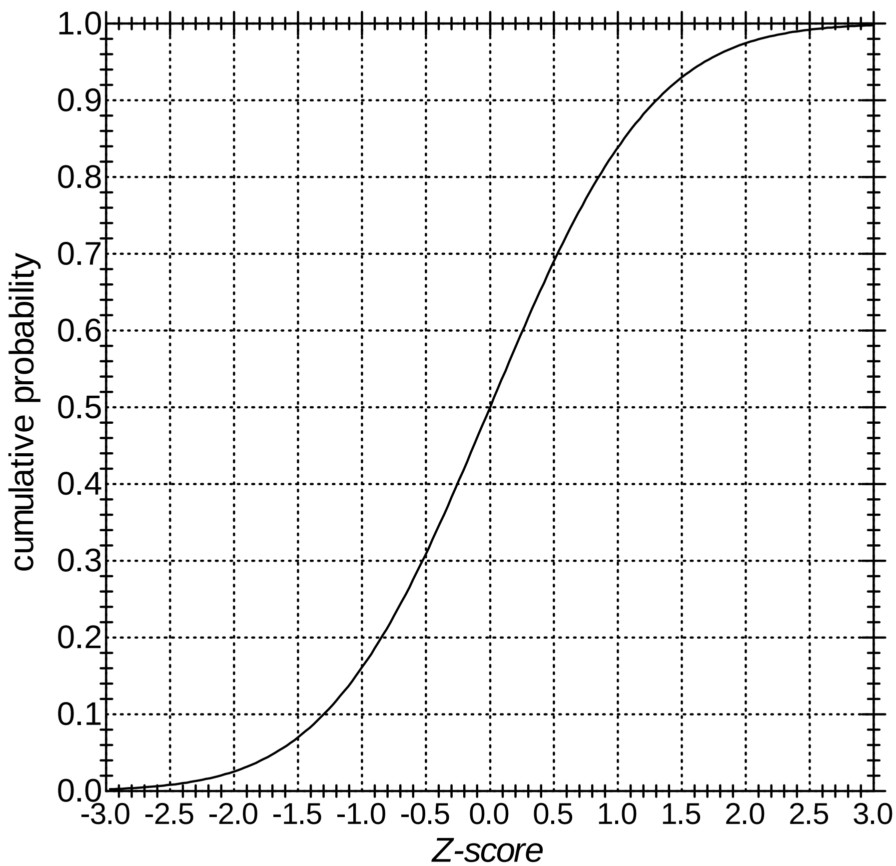
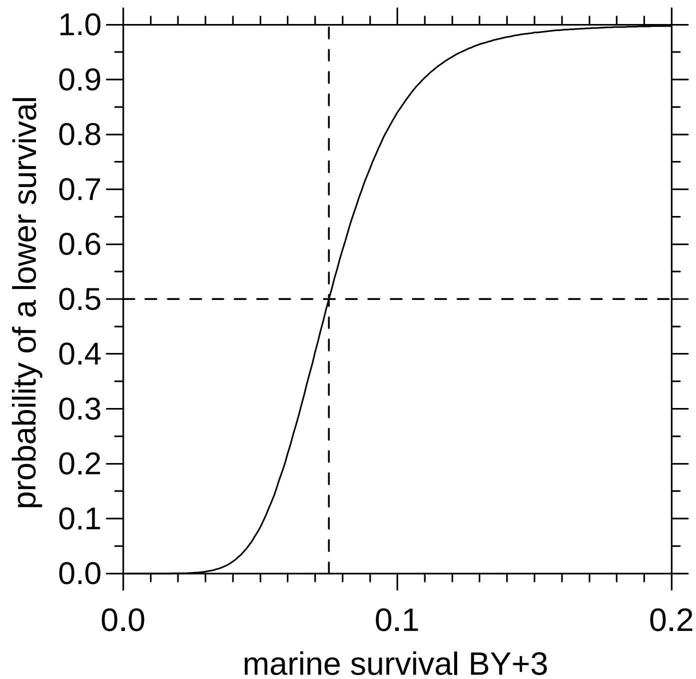


Figure 1. Cumulative probabilities for *Z*-scores applicable to the time series of Babine Lake coho and the average-stream indices from the Statistical Areas. This plot can be used to convert *Z*-scores to probabilities.



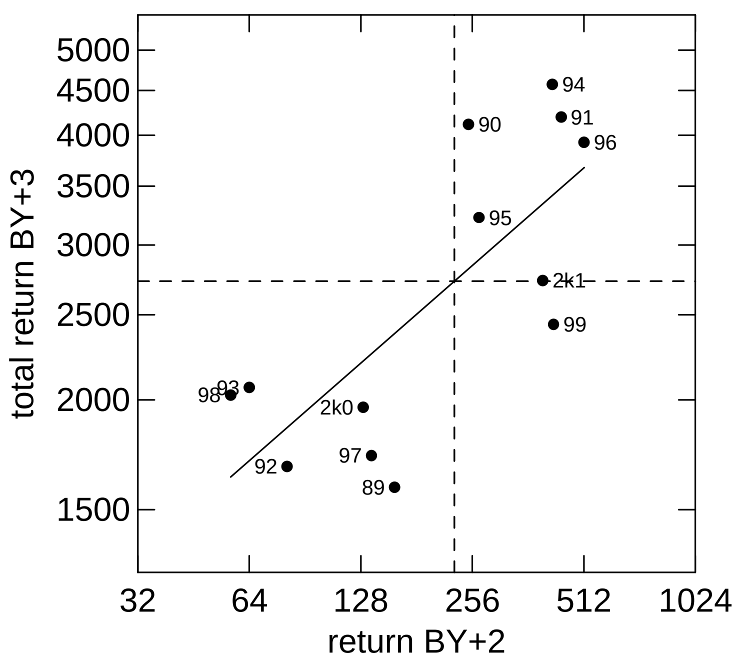


Figure 2. Return and survival forecast for Lachmach River coho in 2002 using the sibling regression model. The lower panel is the sibling relationship. The upper panel is the probability distribution for the predicted marine survival.

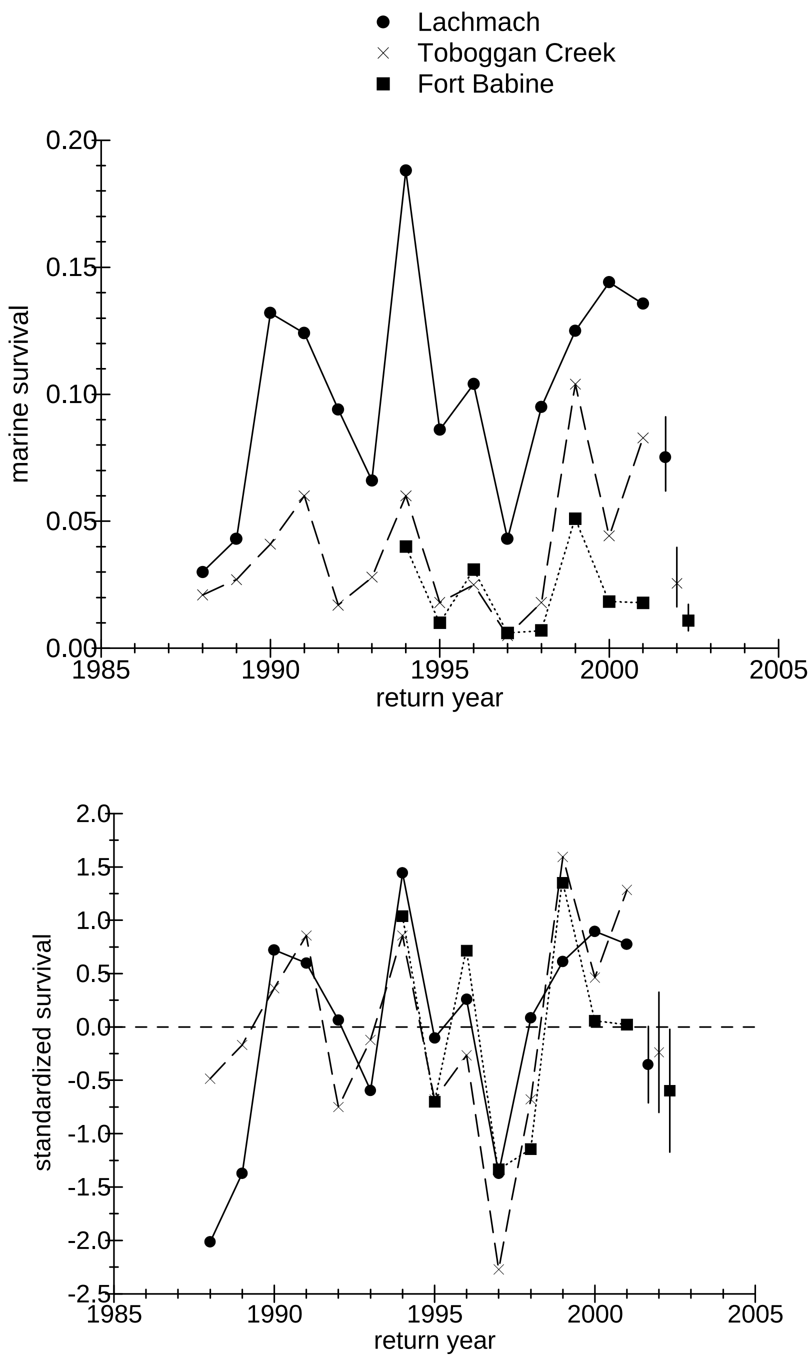


Figure 3. Time series of marine survivals (top) and standardized (bottom) for three northern BC coho indicators. Forecast survivals for 2002 are shown with 50% confidence intervals to the right of the plot.

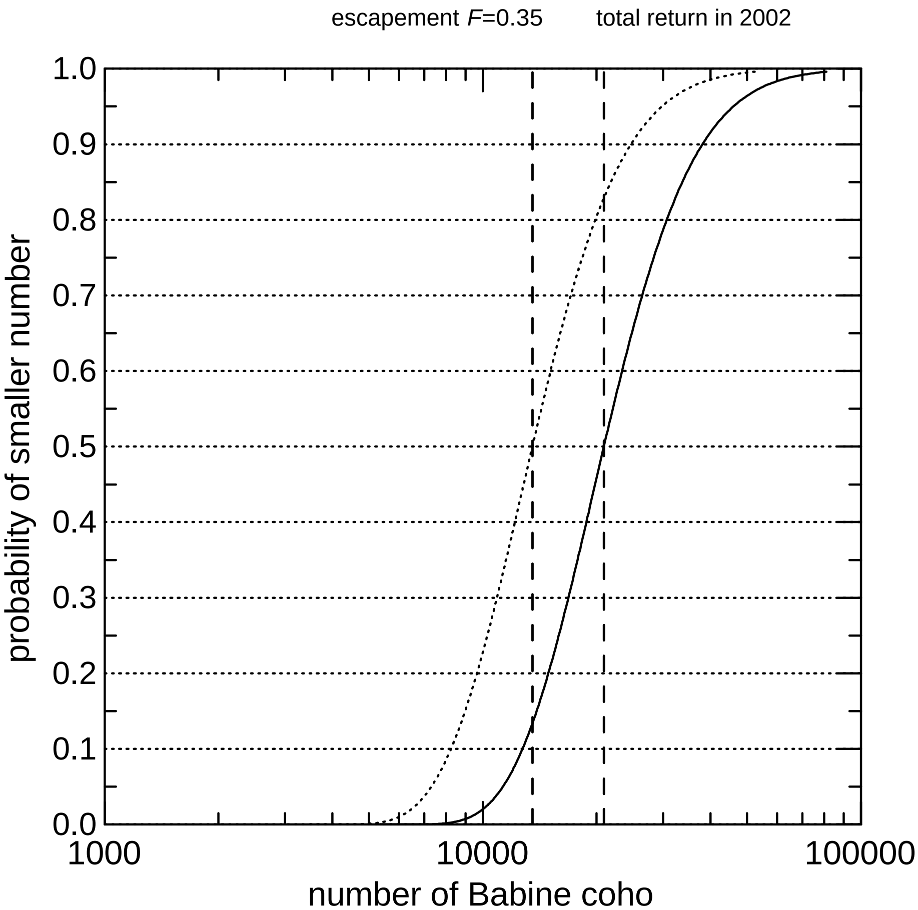


Figure 4. Stock-recruitment forecast for Babine coho aggregate in 2002. Escapement (dotted lines) is forecast for two exploitation rates (0.4 and 0.6). The solid line is the forecast for the total return in 2002. The two vertical dashed lines indicate the point forecasts for total return on the right and after fishing at the rate observed in 2000 of 35%.

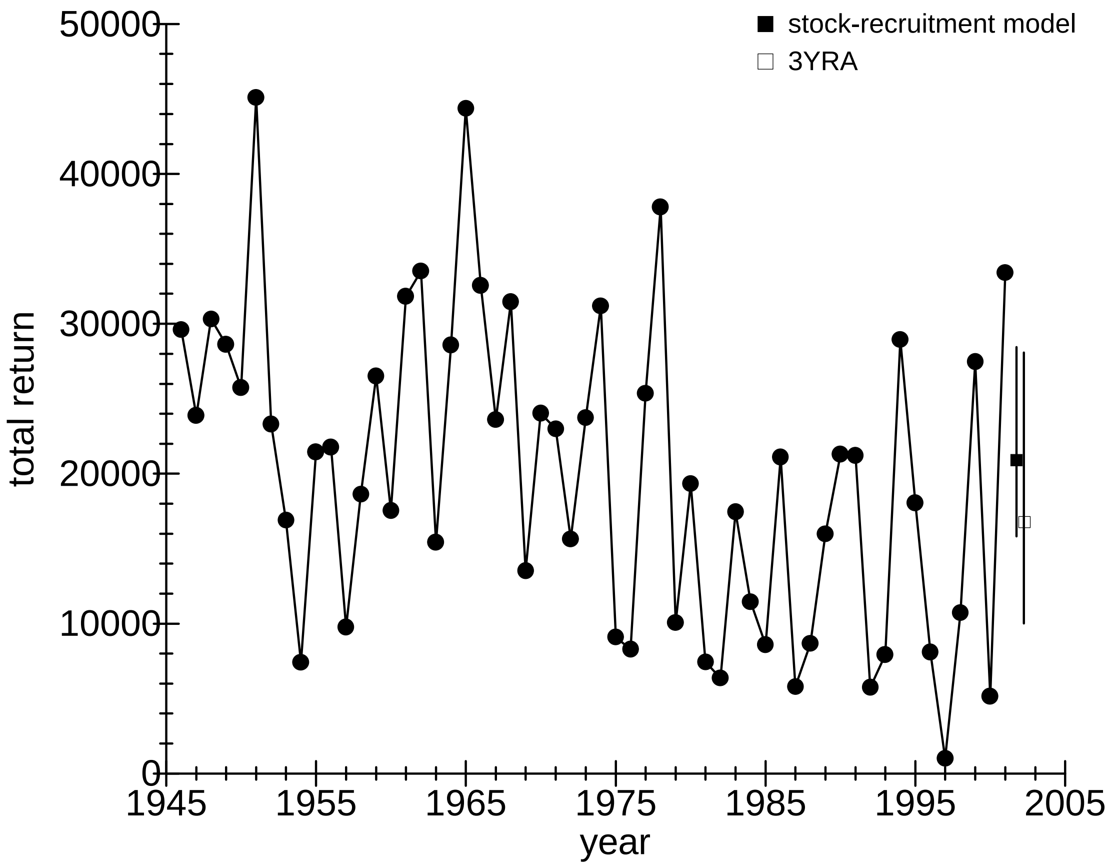


Figure 5. Forecast of total return of the Babine Lake coho aggregate in 2002. The S-R and 3YRA forecasts with 50% CI are shown to the right of the graph. The S-R model is the preferred model.

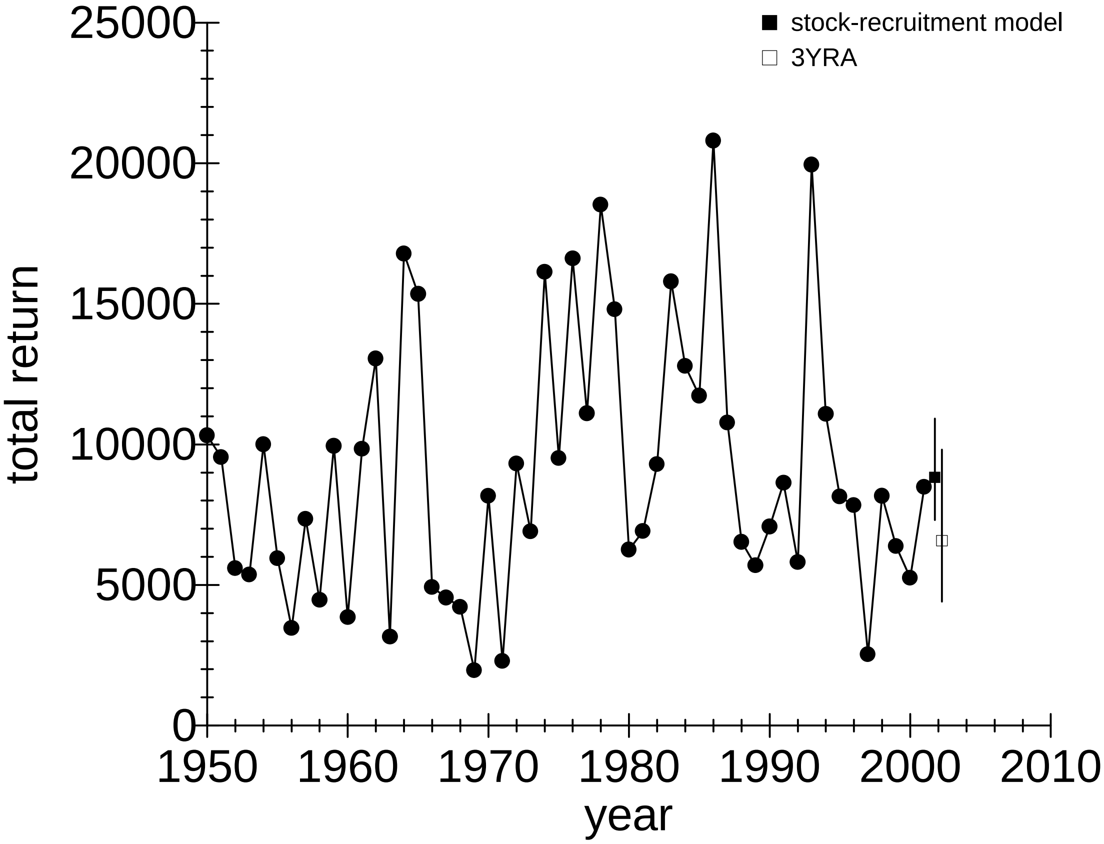


Figure 6. Total return to the average stream in Area 1. The S-R and 3YRA forecasts for 2002 with associated 50% CI are shown to the right of the graph. The 3YRA model is the preferred model.

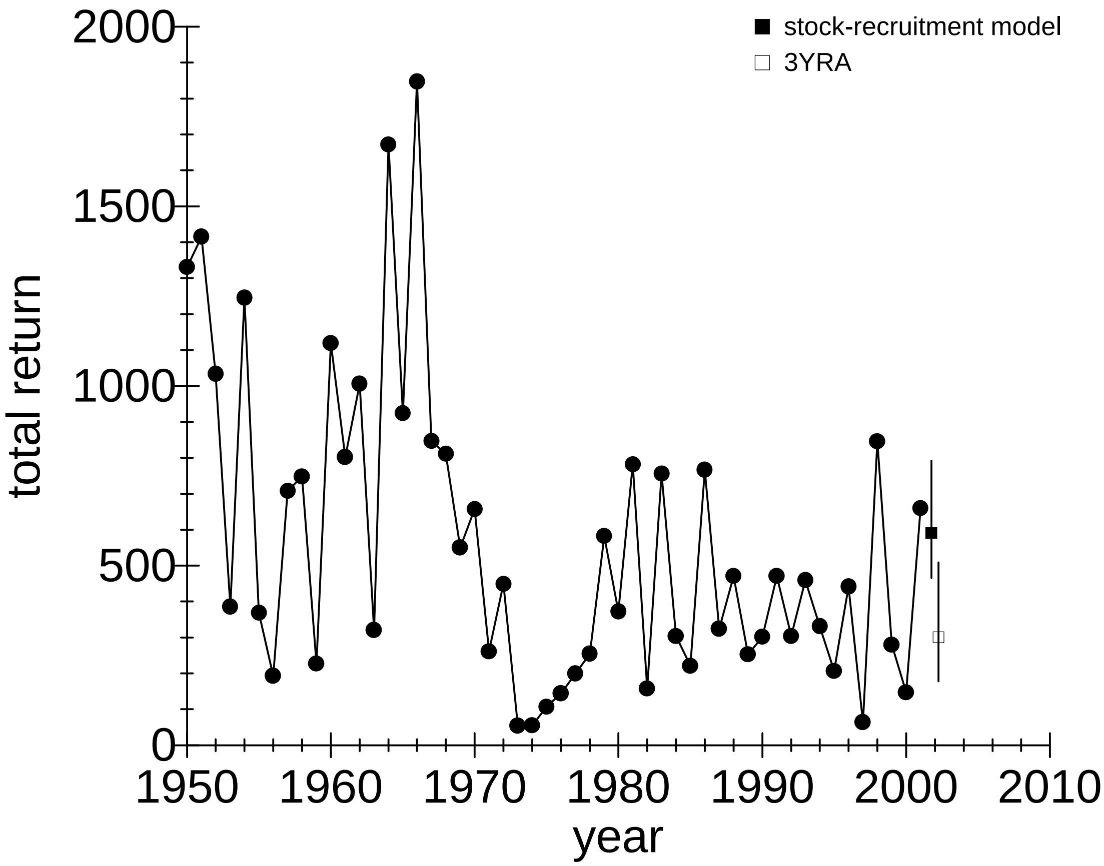


Figure 7. Total return to the average stream in Area 2W. The S-R and 3YRA forecasts for 2002 with associated 50% CI are shown to the right of the graph. The 3YRA model is the preferred model.

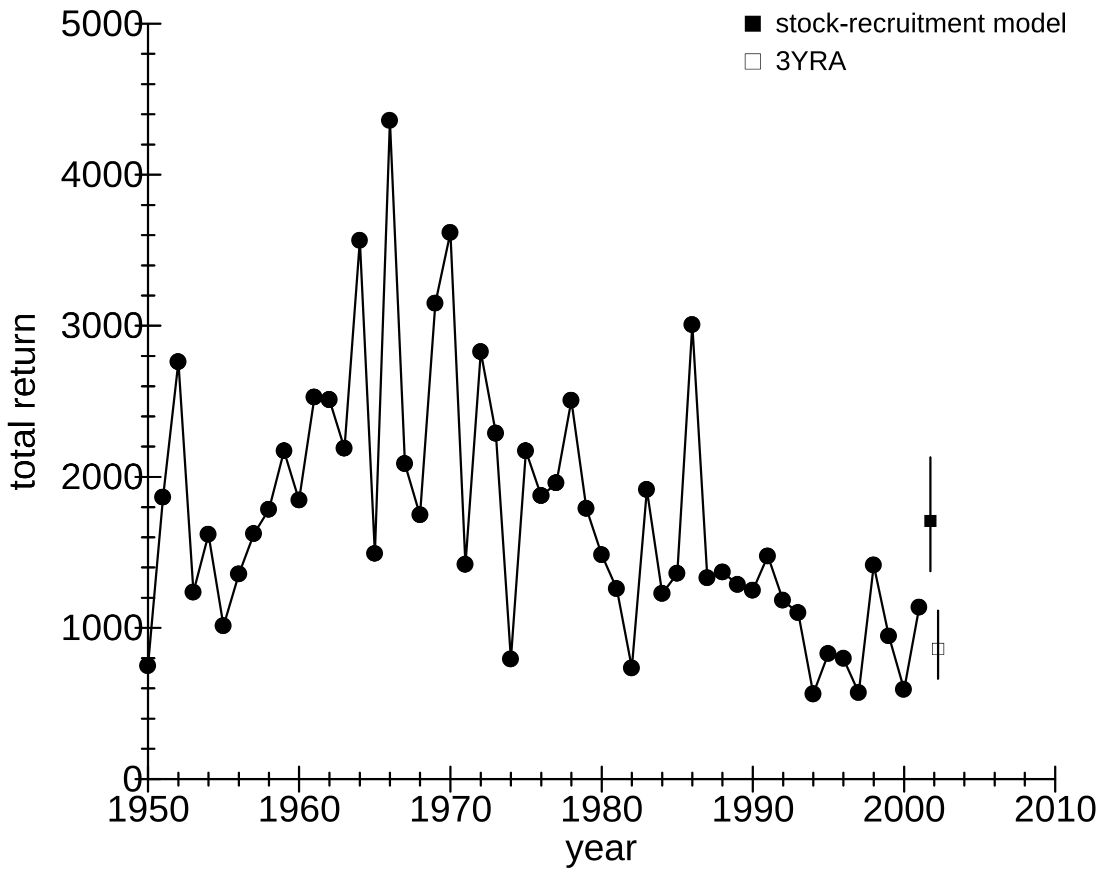


Figure 8. Total return to the average stream in Area 2E. The S-R and 3YRA forecasts for 2002 with associated 50% CI are shown to the right of the graph. The 3YRA model is the preferred model.

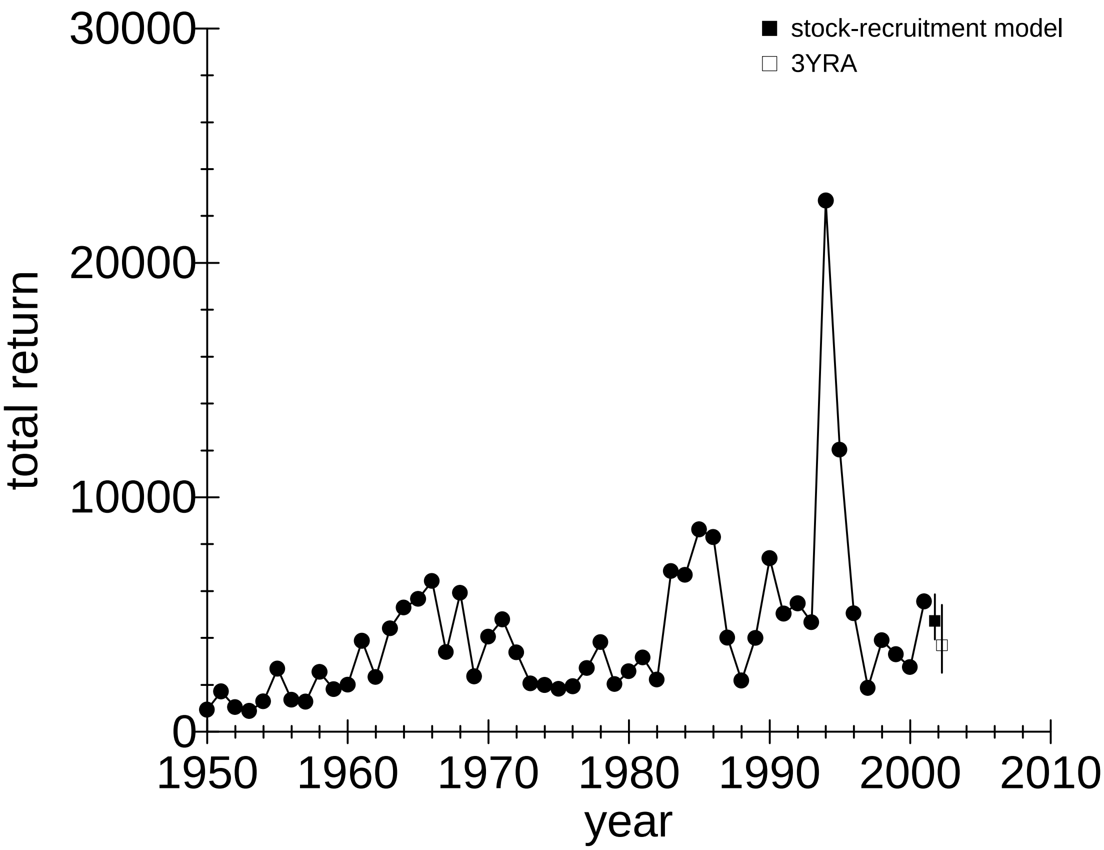


Figure 9. Total return to the average stream in Area 3 including the Nass River and the Lachmach indicator. The S-R and 3YRA forecasts for 2002 with associated 50% CI are shown to the right of the graph. The 3YRA model is the preferred model.

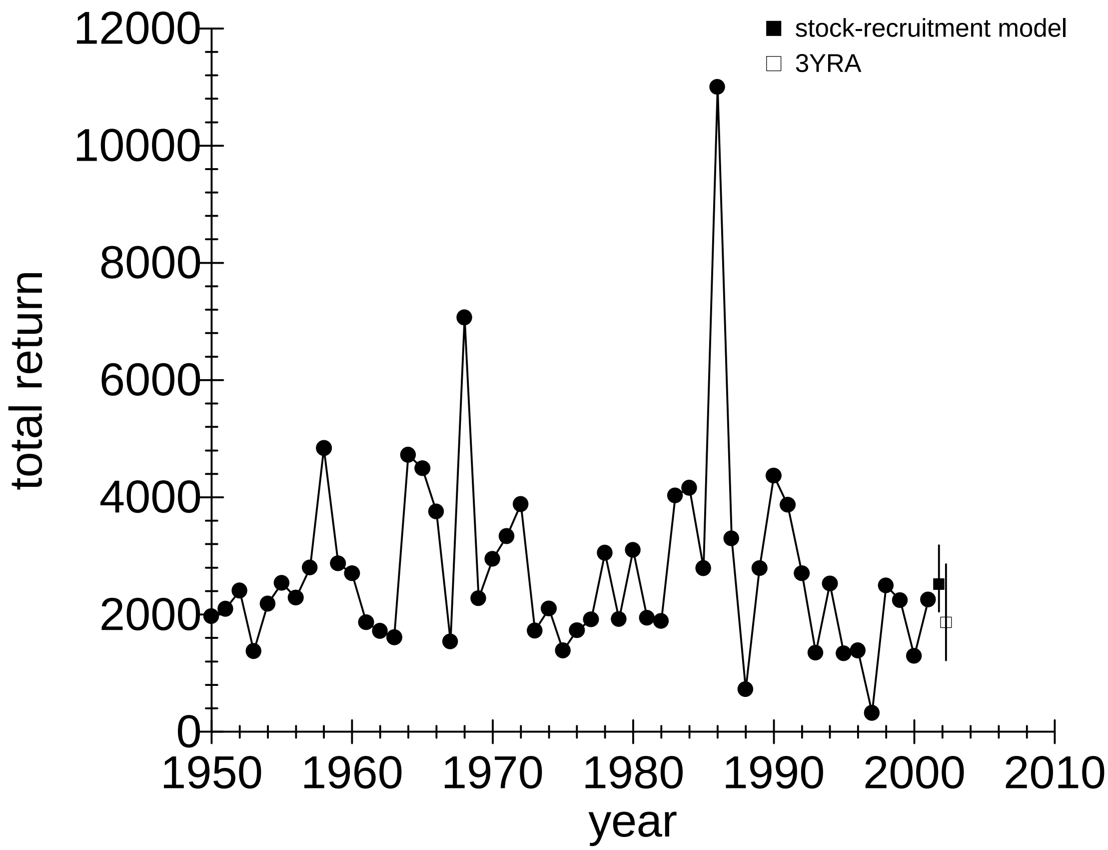


Figure 10. Total return to the average stream in Area 4L, which includes all tributaries of the Skeena between the Alastair and the Kispiox excluding the Bulkely-Morice. The S-R and 3YRA forecasts for 2002 with associated 50% CI are shown to the right of the graph. The 3YRA model is the preferred model.

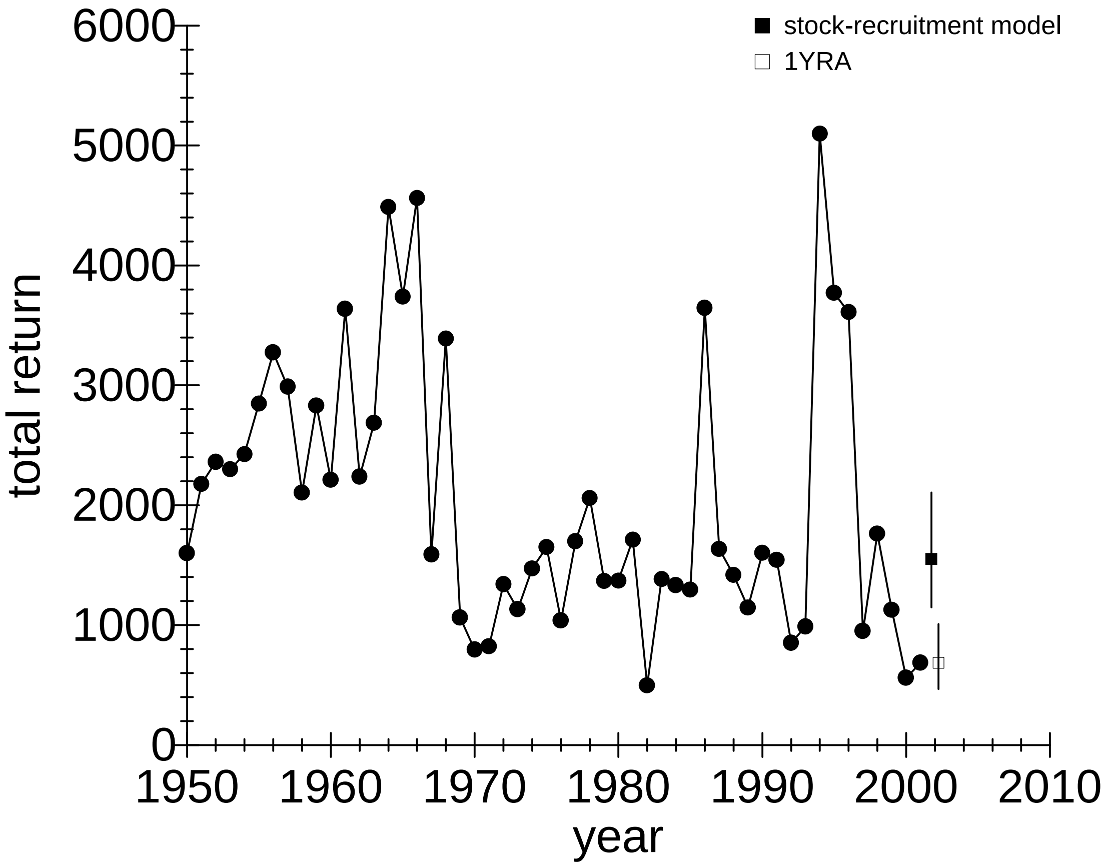


Figure 11. Total return to the average stream in Area 4C-5. The S-R and LLY forecasts for 2002 with associated 50% CI are shown to the right of the graph. The LLY model is the preferred model.

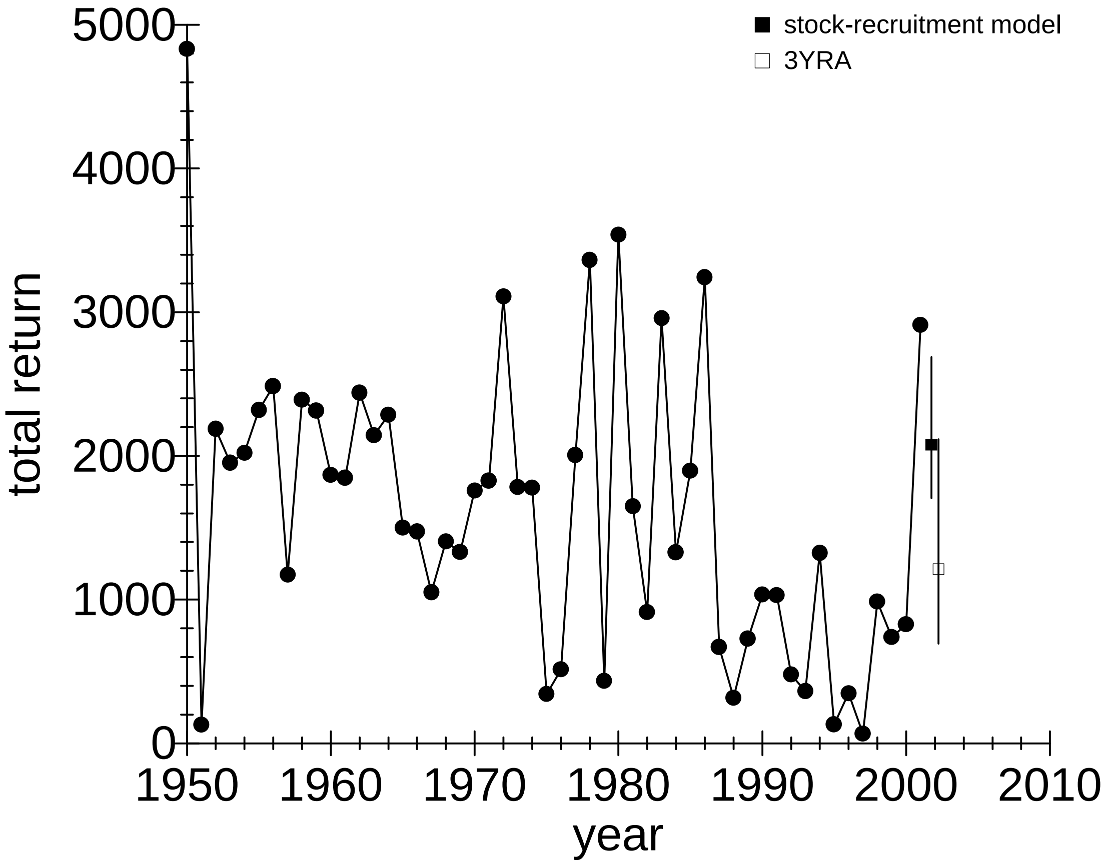


Figure 12. Total return to the average stream in Area 4U, the upper Skeena including the Bulkley/Morice, and all systems upstream of the Bulkley confluence. The S-R and 3YRA forecasts for 2002 with associated 50% CI are shown to the right of the graph. The 3YRA model is the preferred model.

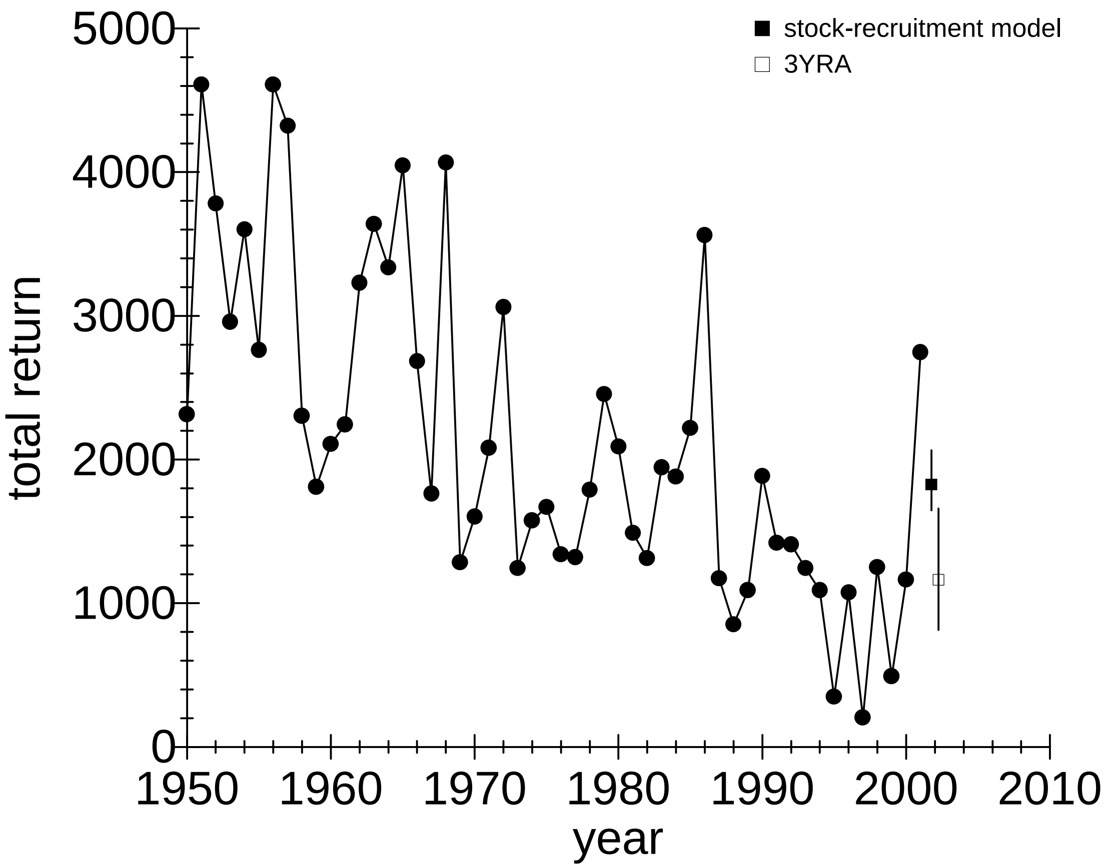


Figure 13. Total return to the average stream in Area 6. The S-R and 3YRA forecasts for 2002 with associated 50% CI are shown to the right of the graph. The 3YRA model is the preferred model.

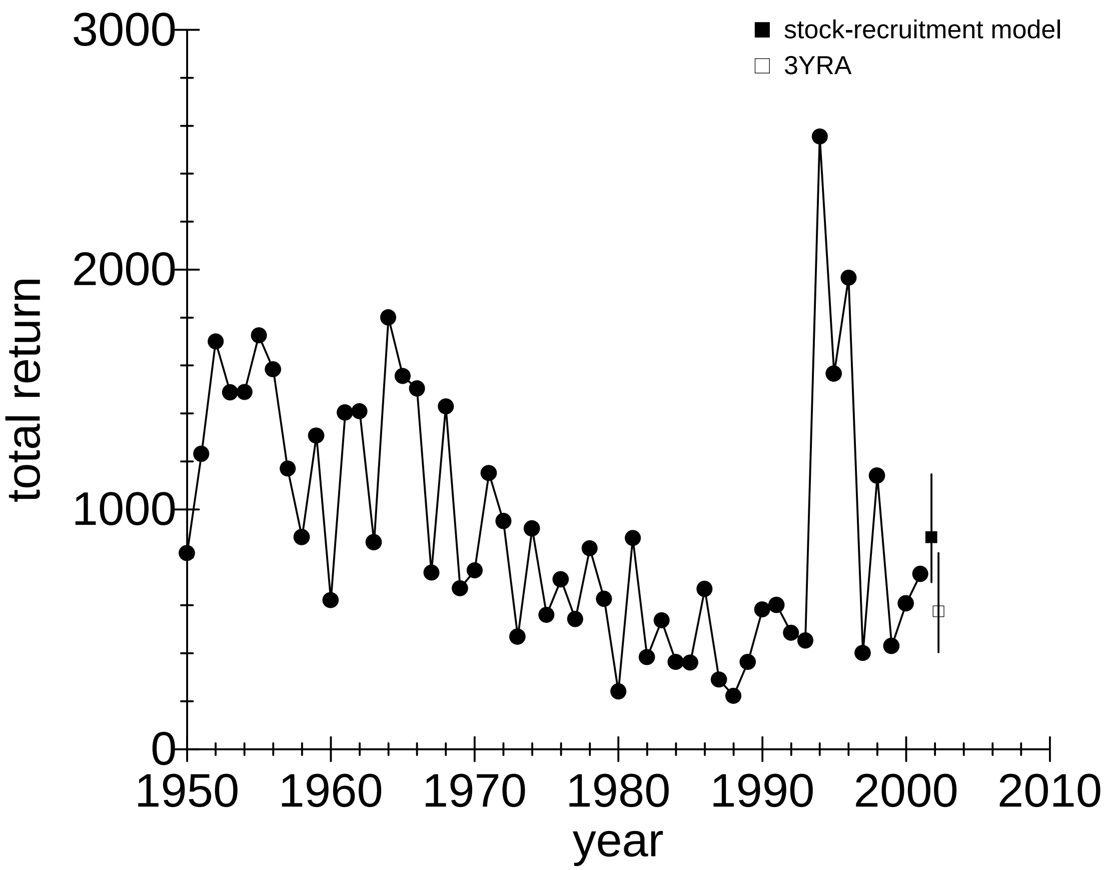


Figure 14. Total return to the average stream in Area 7. The S-R and 3YRA forecasts for 2002 with associated 50% CI are shown to the right of the graph. The 3YRA model is the preferred model.

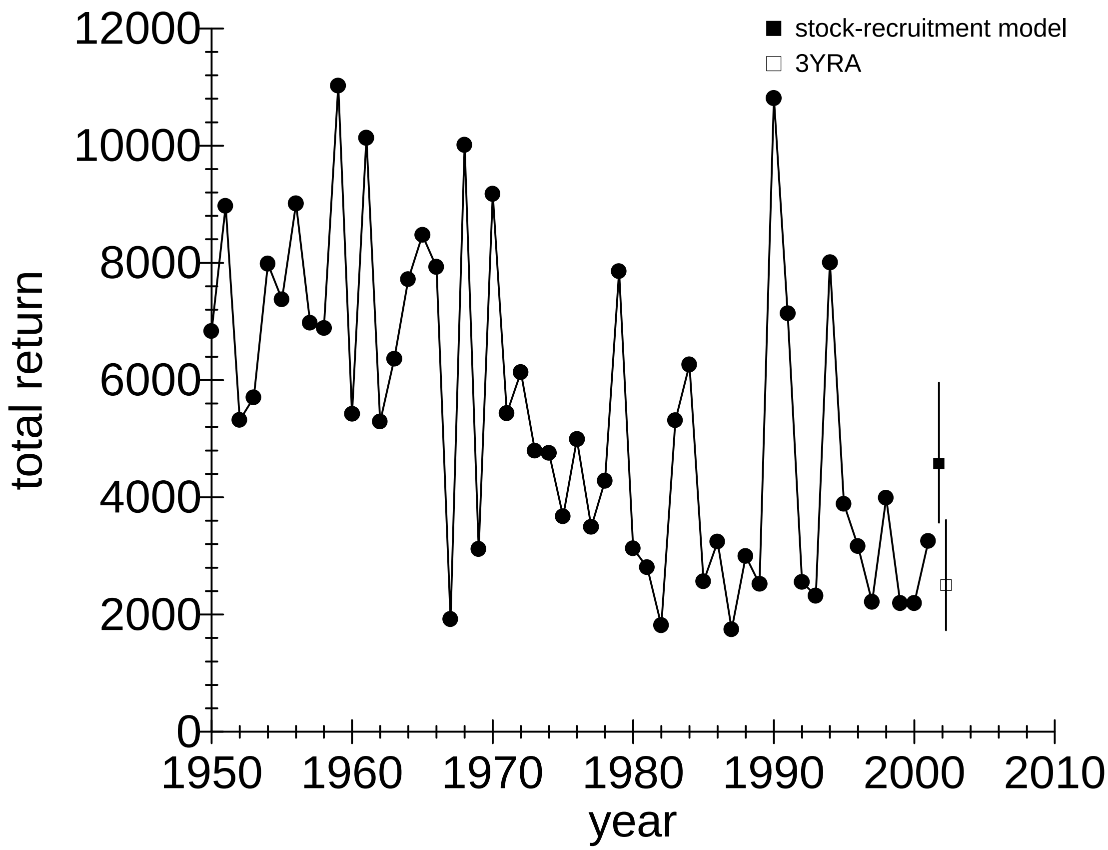


Figure 15. Total return to the average stream in Area 8. The S-R and 3YRA forecasts for 2002 with associated 50% CI are shown to the right of the graph. The 3YRA model is the preferred model.

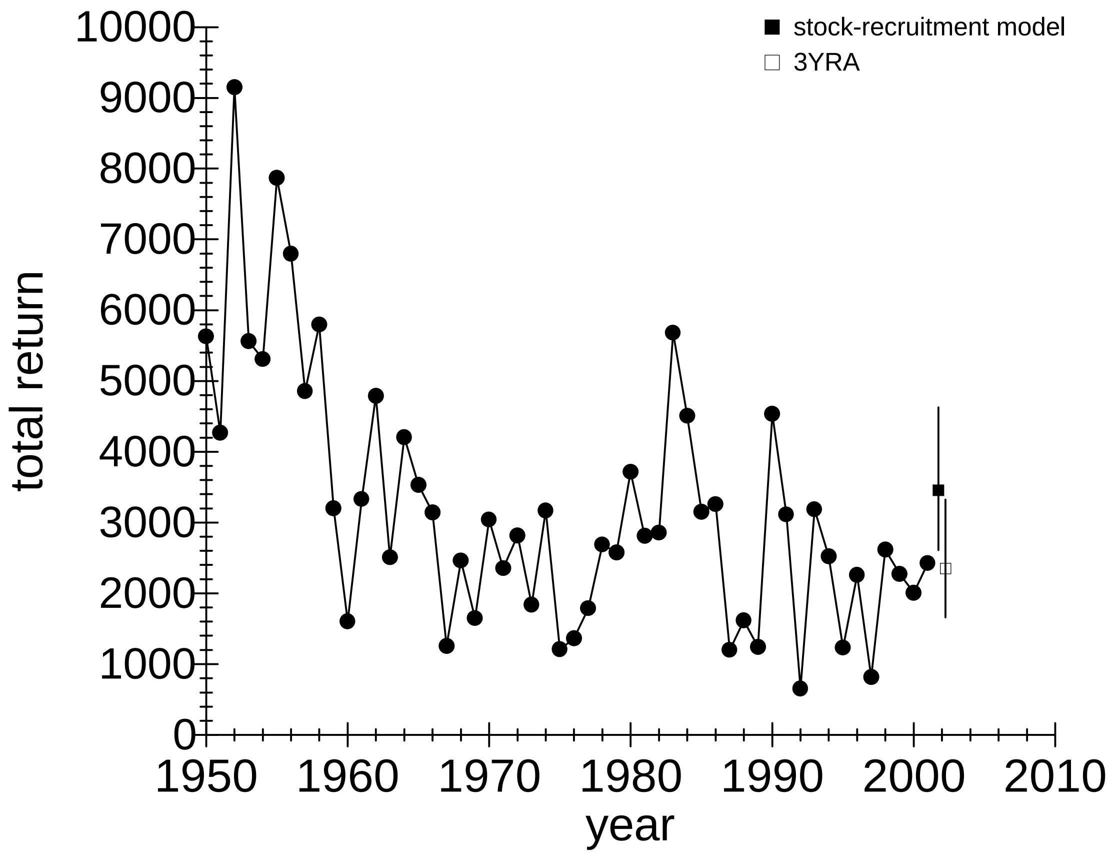


Figure 16. Total return to the average stream in Area 9 to 12. The S-R and 3YRA forecasts for 2002 with associated 50% CI are shown to the right of the graph. The 3YRA model is the preferred model.

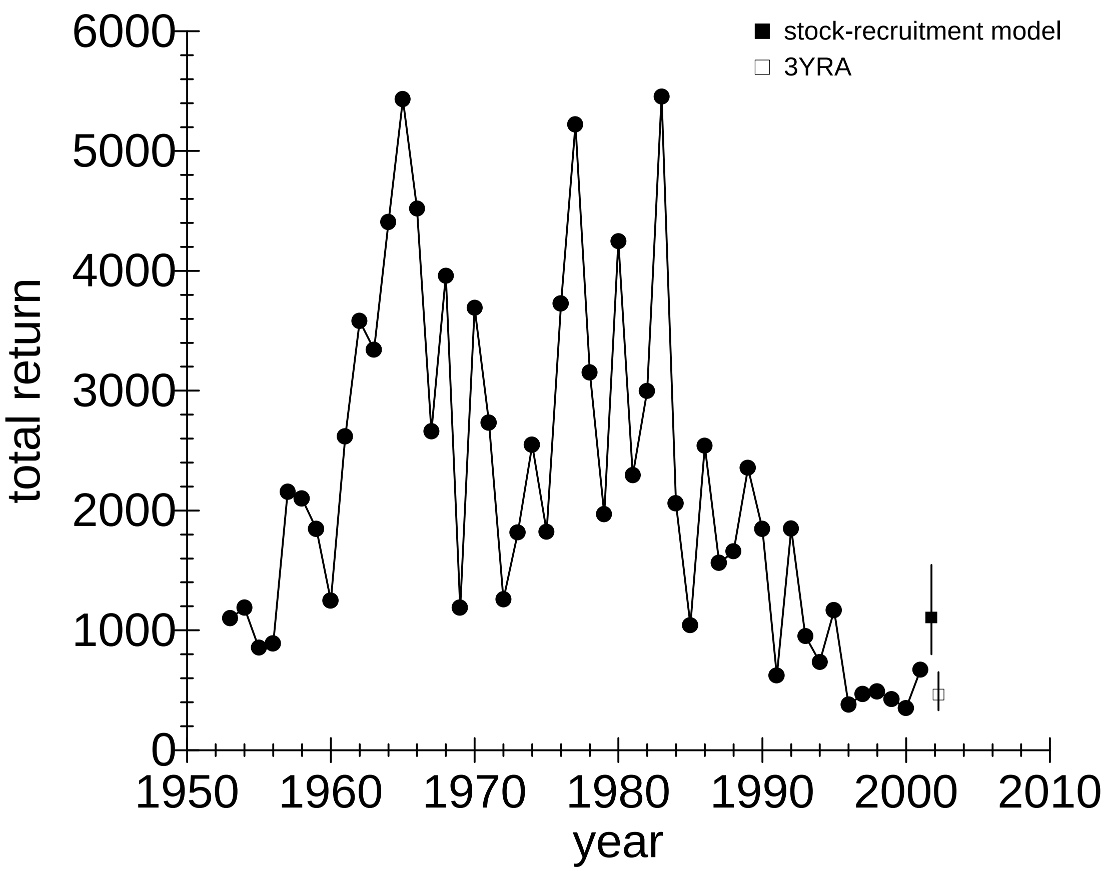


Figure 17. Total return to the average stream in Area 13. The S-R and 3YRA forecasts for 2002 with associated 50% CI are shown to the right of the graph. The 3YRA model is the preferred model.